TECHNOLOGY DEPT.

ENGINEERING CONFERENCE NUMBER

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EDISON ELECTRIC INSTITUTE

CUSTOMERS SERVED BY THE ELECTRIC LIGHT AND POWER INDUSTRY

NUMBER OF CUSTOMERS

(Electric Light & Power Industry) **(100% of Industry)**

By Class of Service
(As of December 31, 1938)

	Total	Farm	Residential	Com. & Ind. Small	Com. & Ind. Large	Str & Hwy Ltg	Other Pub. Author.	Rwys Str	Rwys RR
United States	**27,851,471**	**1,406,579**	**22,110,403**	**3,979,466**	**251,573**	**26,340**	**76,837**	**244**	**29**
Maine	214,632	18,200	160,332	28,780	5,220	391	1,706	3	0
New Hampshire	139,888	10,143	109,033	16,299	2,712	210	1,489	2	0
Vermont	88,886	9,008	64,225	13,697	1,313	212	430	1	0
Massachusetts	1,292,923	21,492	1,084,188	176,145	9,623	499	962	11	3
Rhode Island	200,958	4,000	170,968	24,961	750	41	238	0	0
Connecticut	488,276	21,000	400,089	58,394	8,639	52	98	3	1
New England	*2,425,563*	*83,843*	*1,988,835*	*318,276*	*28,257*	*1,405*	*4,923*	*20*	*4*
New York	3,938,190	93,332	3,207,986	595,677	33,599	1,756	5,800	31	9
New Jersey	1,220,129	21,200	999,931	193,077	2,845	681	2,390	3	2
Pennsylvania	2,357,790	96,034	1,915,121	316,639	21,478	1,813	6,696	6	3
Middle Atlantic	*7,516,109*	*210,566*	*6,123,038*	*1,105,393*	*57,922*	*4,250*	*14,886*	*40*	*14*
Ohio	1,757,510	104,384	1,398,679	233,717	11,687	1,878	7,137	27	1
Indiana	794,126	66,447	605,745	108,422	8,496	890	4,112	14	0
Illinois	1,992,841	58,898	1,665,564	246,437	17,027	1,199	3,700	14	2
Michigan	1,308,231	103,712	1,029,984	168,474	4,313	1,011	732	3	2
Wisconsin	730,689	67,590	554,129	102,708	3,955	1,527	776	4	0
East North Central	*6,583,397*	*401,031*	*5,254,101*	*859,758*	*45,478*	*6,505*	*16,457*	*62*	*5*
Minnesota	547,832	21,910	426,026	96,007	2,484	702	701	2	0
Iowa	520,866	46,973	397,890	72,473	2,263	873	380	14	0
Missouri	731,329	33,423	578,508	113,507	4,199	658	1,032	2	0
North Dakota	81,568	3,449	58,063	18,849	650	377	180	0	0
South Dakota	95,558	3,380	74,200	17,447	125	267	139	0	0
Nebraska	255,888	15,982	192,526	45,366	879	508	624	3	0
Kansas	377,324	20,423	287,634	63,897	2,522	711	2,130	7	0
West North Central	*2,610,365*	*145,540*	*2,014,847*	*427,546*	*13,122*	*4,096*	*5,186*	*28*	*0*
Delaware	56,915	3,045	44,307	8,828	492	63	179	1	0
Maryland-District of Columbia	556,281	16,765	459,772	77,324	1,808	202	405	4	1
Virginia	353,621	28,140	270,790	49,451	3,642	256	1,336	6	0
West Virginia	254,525	13,163	198,023	40,184	1,646	227	1,271	11	0
North Carolina	386,952	37,883	299,562	44,008	3,685	329	1,485	0	0
South Carolina	149,043	17,098	106,424	23,409	1,365	198	549	0	0
Georgia	296,845	21,157	219,690	54,380	1,042	423	152	1	0
Florida	333,340	10,692	265,597	52,803	1,752	953	1,540	3	0
South Atlantic	*2,387,522*	*147,943*	*1,864,165*	*350,387*	*15,432*	*2,651*	*6,917*	*26*	*1*
Kentucky	321,300	15,730	251,938	44,491	6,325	417	2,398	1	0
Tennessee	326,535	26,648	246,695	50,710	1,529	158	793	2	0
Alabama	252,140	27,764	178,520	44,226	1,039	331	260	0	0
Mississippi	129,353	7,587	93,421	25,542	1,609	669	524	1	0
East South Central	*1,029,328*	*77,729*	*770,574*	*164,969*	*10,502*	*1,575*	*3,975*	*4*	*0*
Arkansas	151,406	9,271	109,745	28,496	2,104	305	1,484	1	0
Louisiana	260,660	8,393	208,415	40,210	2,151	205	1,285	1	0
Oklahoma	319,683	14,615	240,337	50,849	11,423	458	1,997	4	0
Texas	882,325	34,796	676,531	153,343	11,504	941	5,203	7	0
West South Central	*1,614,074*	*67,075*	*1,235,028*	*272,898*	*27,182*	*1,909*	*9,969*	*13*	*0*
Montana	104,341	4,847	82,226	15,235	805	186	1,040	0	2
Idaho	109,231	21,428	72,806	13,409	484	144	960	0	0
Wyoming	42,453	2,079	32,768	6,452	1,064	64	26	0	0
Colorado	239,148	11,911	186,912	31,315	8,696	173	141	0	0
New Mexico	46,646	2,300	34,637	9,095	465	99	50	0	0
Arizona	95,801	7,082	74,353	13,403	665	92	205	1	0
Utah	128,819	19,172	93,490	13,357	1,921	205	667	7	0
Nevada	24,451	1,271	18,360	4,418	306	85	11	0	0
Mountain	*790,890*	*70,090*	*595,552*	*106,684*	*14,406*	*1,048*	*3,100*	*8*	*2*
Washington	488,382	50,184	373,708	61,316	1,407	750	1,002	12	3
Oregon	286,646	32,578	207,415	43,558	1,652	238	1,202	3	0
California	2,119,195	120,000	1,683,140	268,681	36,213	1,913	9,220	28	0
Pacific	*2,894,223*	*202,762*	*2,264,263*	*373,555*	*39,272*	*2,901*	*11,424*	*43*	*3*

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EDISON ELECTRIC INSTITUTE BULLETIN

Volume 7 MAY, 1939 No. 5

Record-Breaking Attendance Anticipated at Edison Electric Institute Convention

PREPARATIONS have been made for a record-breaking attendance at the Institute's Annual Convention, to be held at Waldorf-Astoria Hotel in New York, June 6-8.

The Convention will present discussions of vitally important subjects in the most concentrated way possible. The entire business program will consist of three intensive forenoon sessions, starting Tuesday morning, June 6, and entirely devoted to matters with which everyone in the industry is deeply concerned; a World's Fair Session Tuesday afternoon; and a luncheon meeting Thursday, at which Thomas N. McCarter will be the speaker of honor.

This arrangement has been planned in consideration of the fact that New York has this year a World's Fair—and the World's Fair, too, has much to offer of interest to members of the utility industry. On Tuesday afternoon, the Convention will be transplanted directly to the Fair itself, and it is believed that delegates and their guests will want to utilize their remaining free time in New York to see more of the Fair than can be seen in a single afternoon.

The concentrated program does not, however, indicate any decreased importance in the business sessions themselves. It indicates exactly the reverse. Because of the necessity for compressing the usual program into a limited number of sessions, every effort has been made to sift out the most important subjects, and select the most authoritative speakers to deal with those subjects in order that the sessions may present as concise and valuable a program as could possibly be devised.

Speakers to address the Convention include President Kellogg; Floyd L. Carlisle, chairman, Consolidated Edison Company of New York, Inc.; Lenox R. Lohr, president, National Broadcasting Co.; Roy Wenzlick, president, Real Estate Analysts, Inc.; James E. Davidson, president, Nebraska Power Co.; Grover Whalen, president, New York World's Fair; Owen D. Young, chairman, General Electric Company; D. S. Youngholm, vice-president, Westinghouse Electric and Mfg. Co.; A. H. Schoellkopf, president, Electric Utilities Exhibit Corporation; H. E. Dexter, chairman, General Sales Committee, E.E.I.; General Charles Keller, Public Utility Engineering and Service Corporation; George E. Whitwell, vice-president, Philadelphia Electric Company; C. M. Ripley, General Electric Company; H. P. Liversidge, president, Philadelphia Electric Company; Elmo Roper, Distribution Consultant; H. M. Sawyer, vice-president, American Gas and Electric Company; Dr. Adam S. Bennion, Utah Power and Light Company, and Thomas N. McCarter, chairman, Public Service Corporation of New Jersey.

Several committee meetings will be held on Monday, June 5, and registration for the Convention will open at 10 o'clock on the same date. These meetings are listed in the condensed information section, next page, with other information of interest to those expecting to attend the convention.

First Session—Tuesday Morning

The first session will start promptly at 9:30 a.m. Tuesday morning. President Charles W. Kellogg will deliver the opening address.

Roy Wenzlick, president of Real Estate Analysts, Inc., of St. Louis, will follow Mr. Kellogg with a discussion of the outlook for real estate and building development, a subject of vital interest to the future growth and well-being of the electrical industry.

"The Outlook for the Electric Utilities" will be presented by Floyd L. Carlisle, Consolidated Edison Company of New York, Inc. Mr. Carlisle's position in the industry insures a keen analysis of the present utility situation and of its future.

Lenox R. Lohr, president, National Broadcasting Company, will be the final speaker of the session and will discuss the arrival of television, with its significance for the electric industry. (Regular television program broadcasts were begun in New York on April 30.)

Second Session—Wednesday Morning

The Wednesday morning session will open at 10 o'clock with the election of Trustees of the Institute. Four speakers will follow—all well known to the industry both as authorities in their respective subjects and as able platform speakers. First will be H. E. Dexter, Central Hudson Gas and Electric Corporation and chairman of the General Sales Committee of the Edison Electric Institute. His address, "Progress in Building Rural Load," will provide valuable information for every executive concerned with this problem.

General Charles Keller, Public Utility Engineering and Service Corporation, the second speaker at this session, will pre-

Condensed Information on the Edison Electric Institute Convention

New York City, N. Y., June 6, 7 and 8, 1939

All of the business sessions will be held in the Ballroom of the Waldorf-Astoria Hotel, Park and Lexington Avenues, between 49th and 50th Streets. The schedule of events follows:

Monday June, 5th

Registration for the Convention will open at 10 a.m., East Foyer, third floor, and continue until about 5 p.m.

Committee Meetings

Rate Research Committee, 10 a.m.—Room 4-M, fourth floor, Waldorf-Astoria Hotel.

Sales Committee, 10 a.m.—Assembly Rooms 4-J-K-L, fourth floor, Waldorf-Astoria Hotel.

Operating Committee, 1 p.m.—luncheon-meeting, Carpenter Suite, fourth floor, Waldorf-Astoria Hotel.

Tuesday, June 6th

Registration will open at 8:30 a.m., East Foyer, third floor, and continue until the adjournment of the first general session.

First Business Session, 9:30 a.m., Ballroom, third floor.

Ladies' Luncheon. Buses will leave the Waldorf-Astoria Hotel, 49th Street entrance, at approximately 12 noon, to take the ladies in attendance to the World's Fair, where a luncheon will be held for them. All ladies attending the convention are cordially invited. Following the luncheon the ladies will be escorted to the Music Hall to participate in these exercises.

World's Fair Session, 3 p.m. Music Hall at the World's Fair. Guided tours to electric utility exhibits will be provided, following this meeting.

Wednesday, June 7th

Registration will open at 8:30 a.m., East Foyer, third floor, and continue until the adjournment of the second general session.

Second Business Session, 10 a.m., Ballroom, third floor.

Committee Meetings

Board of Trustees, 1 p.m.—luncheon-meeting, Carpenter Suite, fourth floor, Waldorf-Astoria Hotel.

Rate Research Committee, 1 p.m.—luncheon, Assembly Rooms 4-J-K-L, fourth floor, Waldorf-Astoria Hotel.

Executive Committee, Modern Kitchen Bureau, 2:30 p.m., Assembly Rooms 4-N-P-R, fourth floor, Waldorf-Astoria Hotel.

Thursday, June 8th

Registration will open at 9 a.m., East Foyer, and continue until adjournment.

Third Business Session, 10 a.m., Ballroom, third floor.

Luncheon Meeting. All delegates are invited to attend the luncheon-meeting which will be held at 1 p.m. in the Ballroom of the Waldorf-Astoria Hotel. Tickets will be available at $3.00 per person. The Convention will adjourn at the conclusion of this luncheon.

Hotels

The Hotel Circular, giving information regarding hotels, rates, locations, etc., has been mailed to the members of the Institute. Additional Circulars will be sent upon request.

The Institute has been able to make a general reservation for a limited number of rooms at several hotels, for the convenience of convention delegates. The period for these block reservations will expire in advance of the convention, and for this reason, individual reservations should be made as promptly as possible.

Transportation to the World's Fair

Transportation to the Fair Grounds is simple, fast and convenient. The visitor has a choice of three subway systems, the Long Island Railroad, buses, taxicabs and private conveyances.

The time by subway is 20 to 30 minutes, depending on traffic conditions, by the Long Island Railroad from the Pennsylvania Station, 14 minutes, by bus or taxi 30 to 40 minutes.

Subways

I.R.T.—nearest station to Waldorf-Astoria, 1 block, 51st and Lexington Avenue, and change at Grand Central Station.

B.M.T.—nearest station, 10 blocks, 60th Street and Lexington Avenue.

Independent—3 blocks, 53rd Street and Lexington Avenue.

Note: World's Fair stations of the I.R.T., B.M.T. and Long Island Railroad are adjacent to Exhibit Area. World's Fair Station of the Independent Subway is adjacent to the Music Hall, where the World's Fair Session will be held, and to Amusement Area. It is suggested that this line be used to reach the Fair for the Fair Session Tuesday afternoon. Intra-mural buses connect all stations with all parts of Fair Grounds.

Buses

Fifth Avenue Coach—any bus on Fifth Avenue or 57th Street marked "World's Fair." Deluxe express bus service from Fairway Terminal, 50th Street, west of Sixth Avenue.

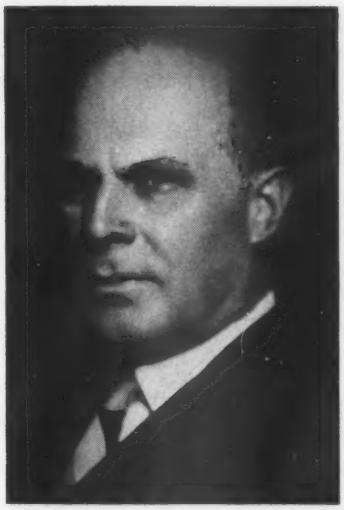
Train

Long Island Railroad—Special World's Fair trains leave Pennsylvania Station every 10 minutes. Time 14 minutes. Fare 10¢.

Private Conveyances

Blue and gold Trylon-Perisphere signs and golden street lights mark all main routes to the Fair. Keep signs and lights to your right when driving to the Fair, and to your left when leaving.

FLOYD L. CARLISLE
Chairman, Consolidated Edison Co. of New York, Inc.



CHARLES W. KELLOGG
President, Edison Electric Institute

THOMAS N. McCARTER
Chairman, Public Service Corporation of New Jersey

sent "War Procurement and Electric Power Supply" and will shed light on a subject which has been in the headlines to a considerable extent in recent months.

"Balanced Load Building" will be discussed by George E. Whitwell, Philadelphia Electric Company, whose accomplishments as a sales executive are known throughout the industry.

Final speaker at this session will be C. M. Ripley, General Electric Company, who takes as his subject "The Work That a Kilowatthour Can Do." There will be no afternoon session on Wednesday.

Third Session—Thursday Morning

The Thursday morning session will begin at 10 o'clock with the announcement of prize awards. H. P. Liversidge, Philadelphia Electric Company, and chairman of the Institute's Prize Awards Committee, will announce winners of the B. C. Forbes Prize, James H. McGraw Prizes, R. B. Marshall Prizes, Claude L. Matthews Valor Award, Augustus D. Curtis Award and the National Electric Water Heating Council Award.

Presentation of the Charles A. Coffin Award will follow, and conclude the first part of this program.

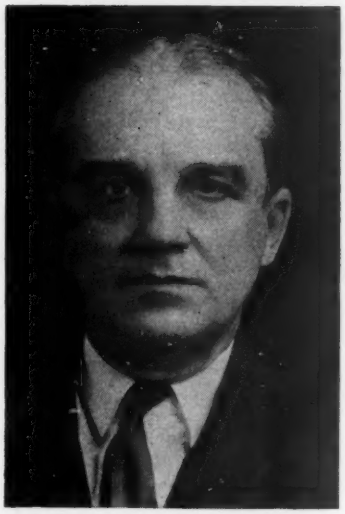
"What the Customer Thinks of Utilities" will be discussed by Elmo Roper, Distribution Consultant of New York. With public opinion changing faster than ever these days, and with intensive efforts to shape public opinion this way or that being made by pressure groups of every complexion, the subject is one in which every delegate will find much of benefit.

"The Case for Central Station

H. M. SAWYER
Vice-President, American Gas and Electric Company

LENOX R. LOHR
President, National Broadcasting Company

A. H. SCHOELLKOPF
President, Electric Utilities Exhibit Corporation



OWEN D. YOUNG
Chairman, General Electric Company

GROVER WHALEN
President, New York World's Fair

D. S. YOUNGHOLM
Vice-President, Westinghouse Elec. and Mfg. Co.

Power" will be presented by H. M. Sawyer, American Gas and Electric Company, who will discuss the selling points of our industry as opposed to isolated power sources.

Dr. Adam S. Bennion, Utah Power and Light Company, will be the final speaker. His subject, "Human Interdependence," may be counted on to emphasize the human side of the utility industry—the man power behind generators and distribution lines and in offices. Announcement of officers for the ensuing year will be followed by adjournment, after which there will be a luncheon meeting at the Hotel for delegates and friends.

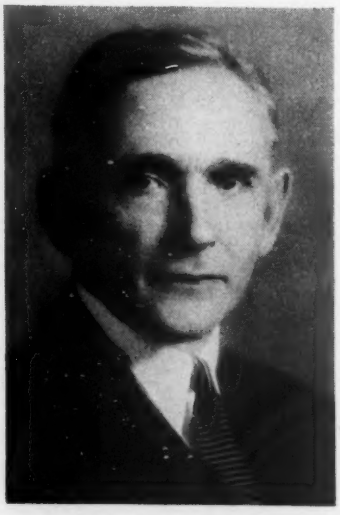
Luncheon Session—Thursday

The speaker at the luncheon meeting will be Thomas N. McCarter, Public Service Electric and Gas Company. A former president of the Institute, Mr. McCarter is known throughout the industry for his unusually capable leadership, vision and wit. Mr. McCarter's address will be the concluding event of the Convention.

World's Fair Session—Tuesday Afternoon

Tuesday afternon, June 6, Edison Electric Institute Day at the Fair, convention delegates will assemble at 3 o'clock at the Music Hall in the World's Fair Grounds for the Fair Session. Tickets for the Fair Grounds will be provided delegates at the convention registration desk.

James E. Davidson, president, Nebraska Power Company, and vice-president of the Institute, will preside at this session which is designed primarily as an introduction of delegates and the pub-



DR. ADAM S. BENNION
Utah Power and Light Company

GEO. E. WHITWELL
Vice-President, Philadelphia Electric Company

HARRIS E. DEXTER
Chairman, General Sales Committee, E.E.I.

GENERAL CHARLES KELLER
Public Utility Engineering and Service Corporation

H. P. LIVERSIDGE
President, Philadelphia Electric Company

JAMES E. DAVIDSON
President, Nebraska Power Company

lic to the electrical exhibits at the Fair. The Convention will be welcomed by Grover Whalen, the Fair's president, who will be followed by Floyd L. Carlisle, Consolidated Edison Company; Owen D. Young, General Electric Company; D. S. Youngholm, Westinghouse Electric and Manufacturing Company, and A. H. Schoellkopf of the Electric Utilities Exhibit Corporation, who will briefly discuss the exhibits at the Fair staged by their organizations. After the introductory talks, guided tours will be made to the several electrical exhibits.

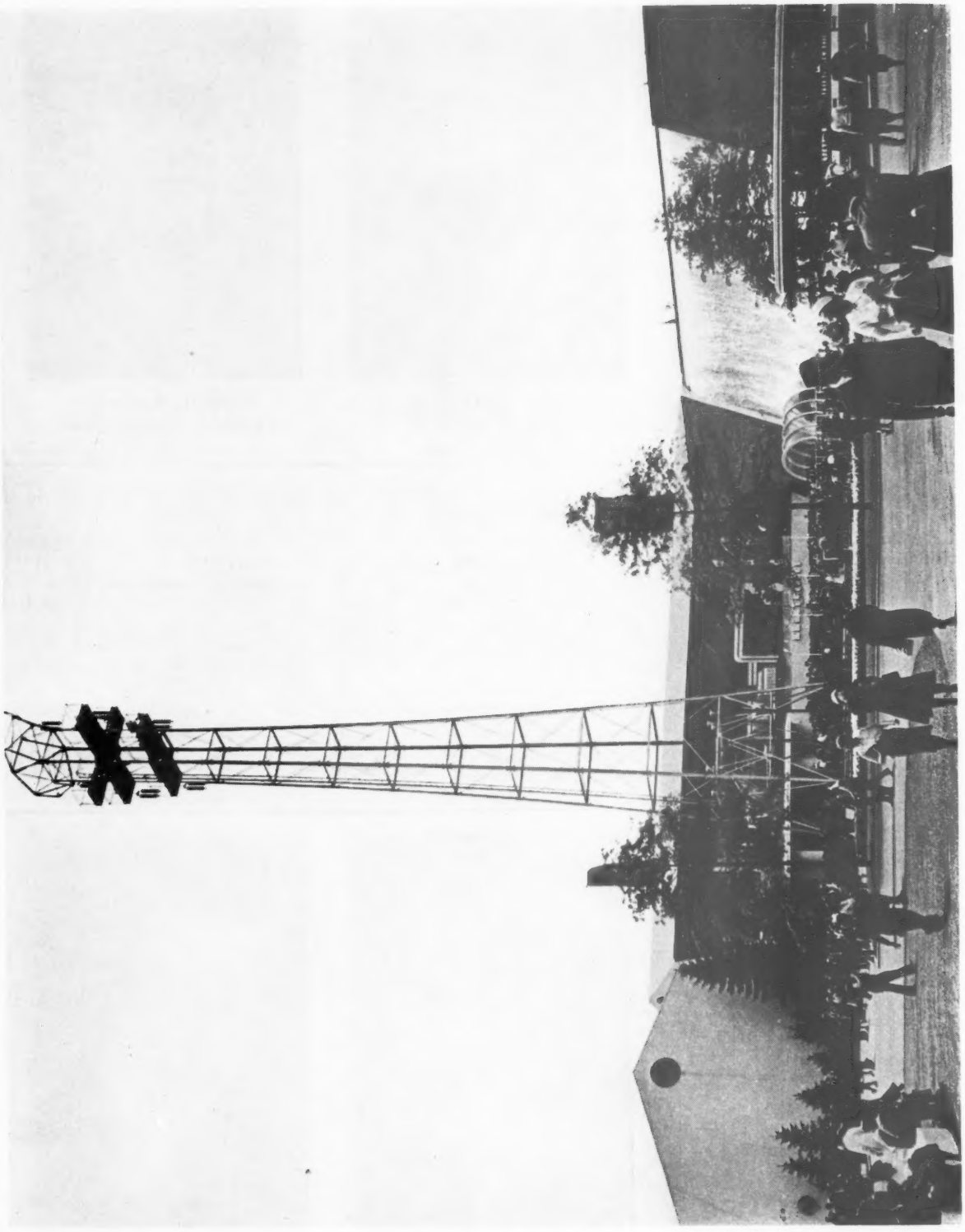
A luncheon for the ladies attending the Convention will be held on the same day in the Atlantic Gardens of the Old New York Restaurant at the Fair. Buses to this restaurant will leave the Waldorf-Astoria at noon on Tuesday. All ladies registering will receive the Convention button and a ticket of admission to the Fair Event. Wives of representatives of local companies attending the Convention, as well as those coming from a distance, are cordially invited to attend this affair. After the luncheon the ladies will be escorted to the Music Hall to participate in the World's Fair Session.

Every effort will be made to provide for the comfort and convenience of those attending the Convention. The registration and information desks of the Institute will be at the service of delegates, and all members of the general office staff will be glad to extend all possible courtesies. Visitors to New York at this time will also find the hotels, restaurants, shops, public agencies of the city, and the World's Fair staffs intent on giving their best services.

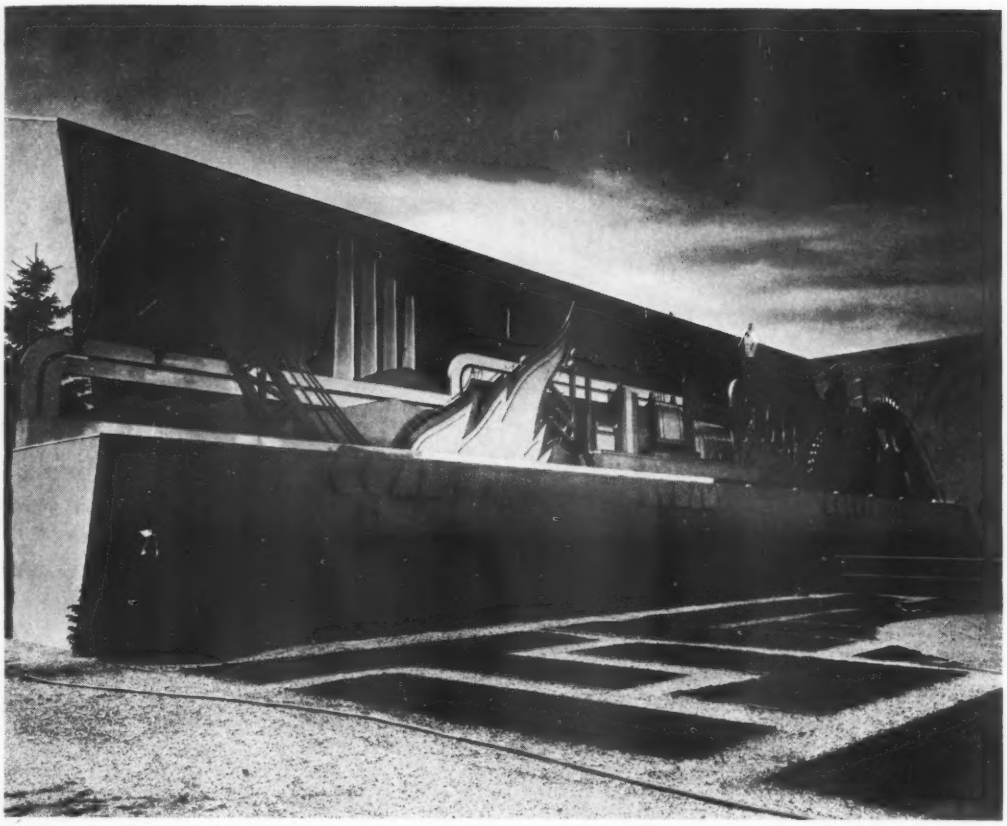
ELMO ROPER
Distribution Consultant, New York

C. M. RIPLEY
General Electric Company

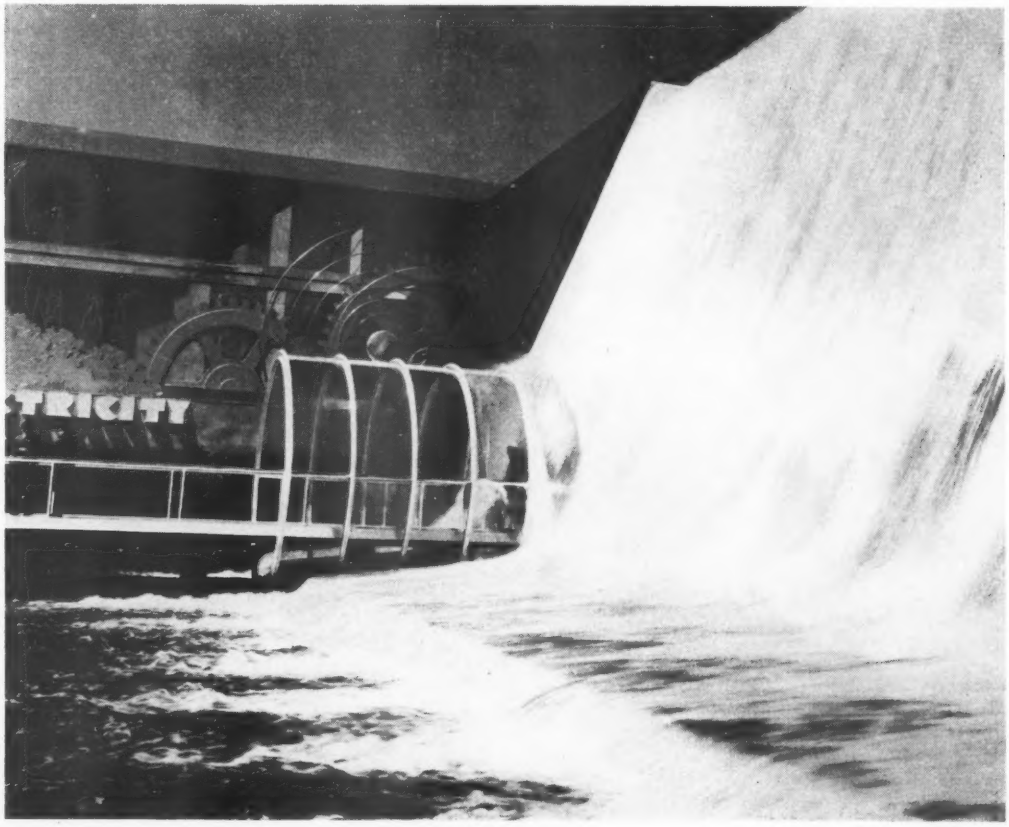
ROY WENZLICK
President, Real Estate Analysts, Inc.

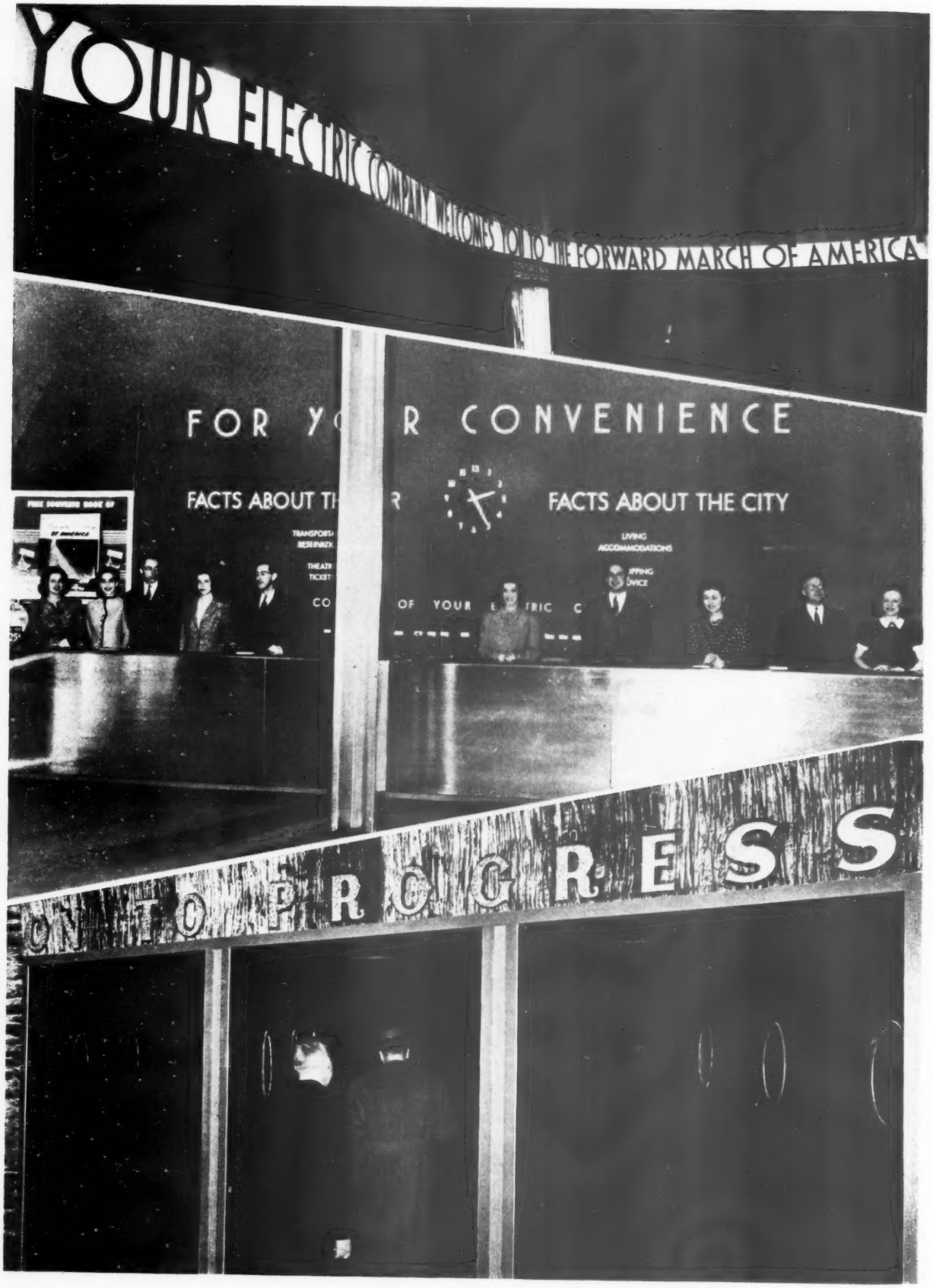


Forward March of America—Exhibit of Electric Utilities Exhibit Corporation



Two close-ups from Forward March of America

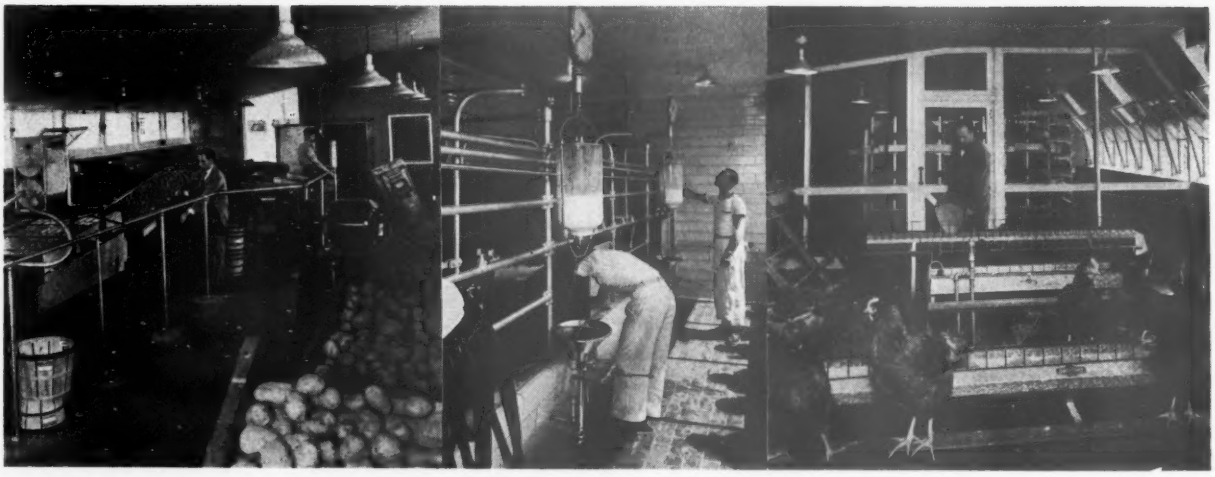



YOUR ELECTRIC COMPANY WELCOMES YOU TO THE FORWARD MARCH OF AMERICA
FOR Y R CONVENIENCE
FACTS ABOUT TH
FACTS ABOUT THE CITY
LIVING ACCOMMODATIONS
OF YOUR
ON TO PROGRESS

The Street of Yesterday and a part of the Avenue of Tomorrow

—

Forward March of America



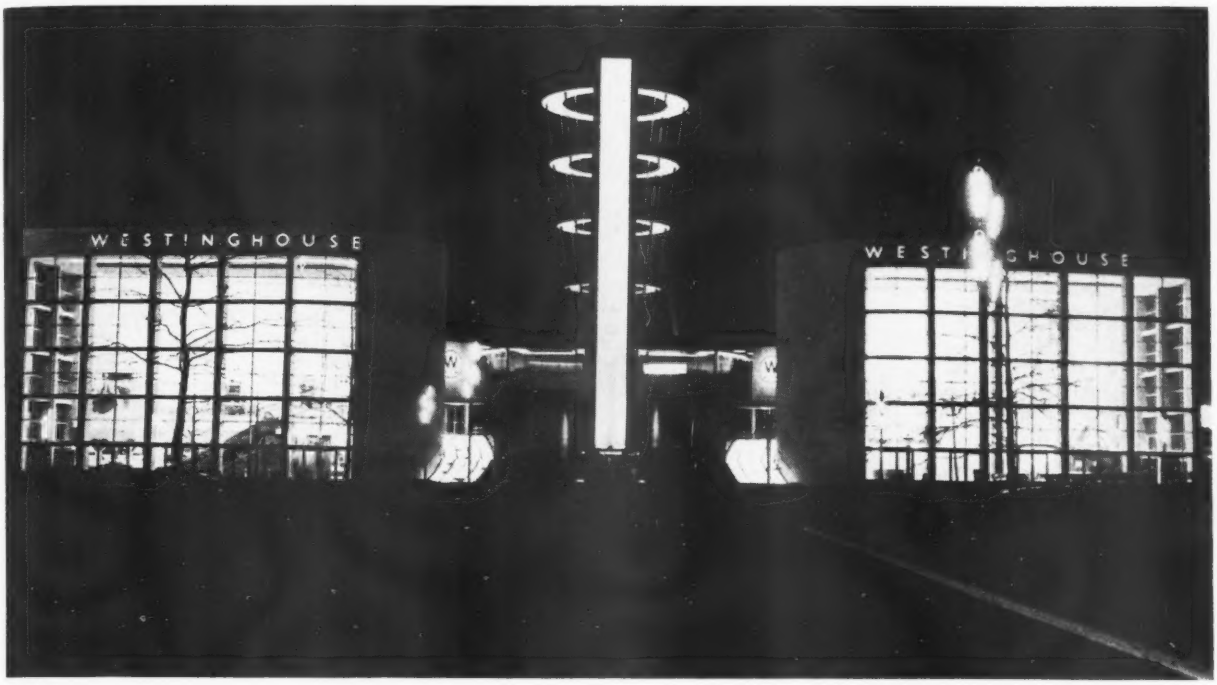
Some shots at the Electrified Farm. Both Forward March of America and the Electrified Farm are drawing a tremendous attendance. The Personal Service Bureau at Forward March of America has been termed the best in the Fair by those who know what is being done by the Fair itself and by individual exhibitors

This view of the Electrified Farm living room shows that life is not all work and no play for farmers who use electricity to do the chores

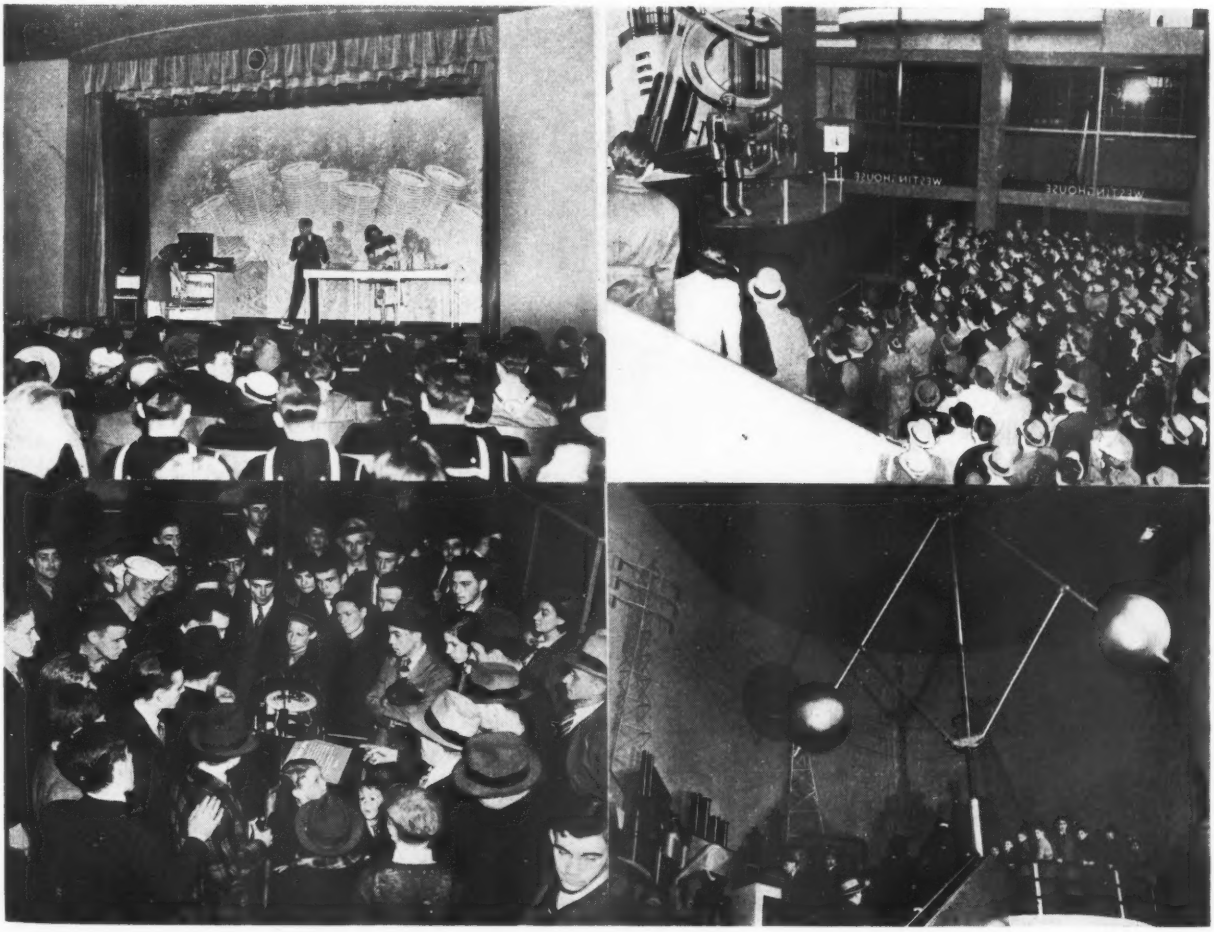
Just by regulating the amount of light given plants, they can produce any flower they want at any season of the year, in the Electrified Farm greenhouse

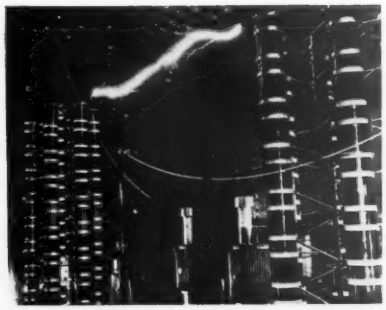
Planned for assembly-line efficiency, the kitchen of the Electrified Farm is a home-maker's dream. This picture shows Muriel, top-flight cook of the Electrified Farm. Muriel not only cooks, she talks about it through her lapel-microphone to the crowds that gather at the windows

The City of Light—Consolidated Edison's Exhibit



The Westinghouse Building and some of its exhibits

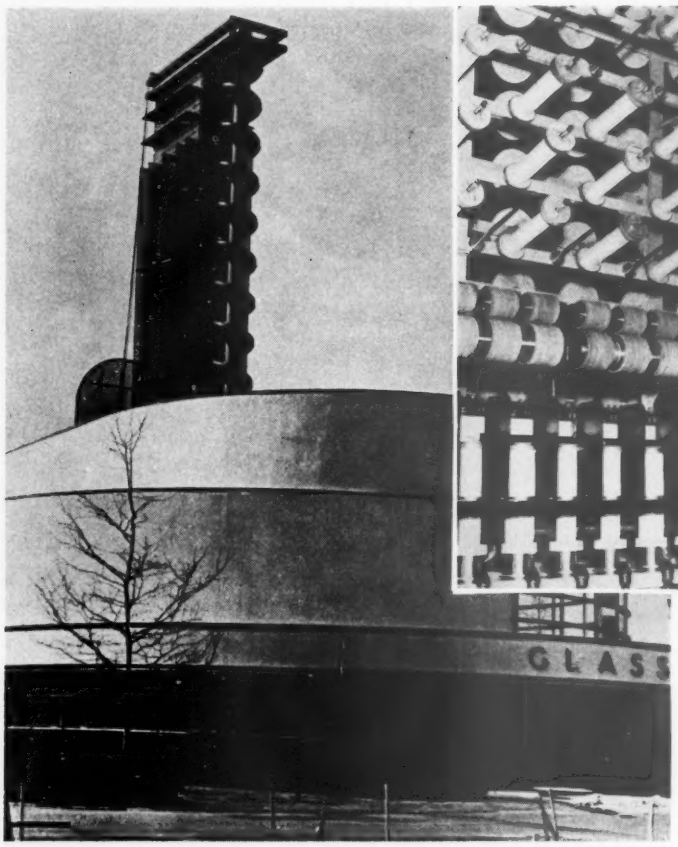


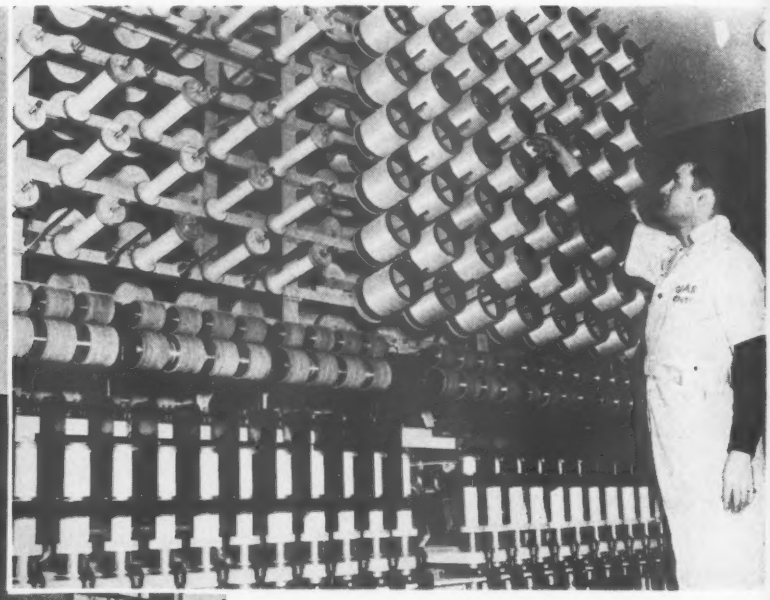


General Electric's Building and some of the things to see in it

Section of the Copper and Brass Industry Exhibit

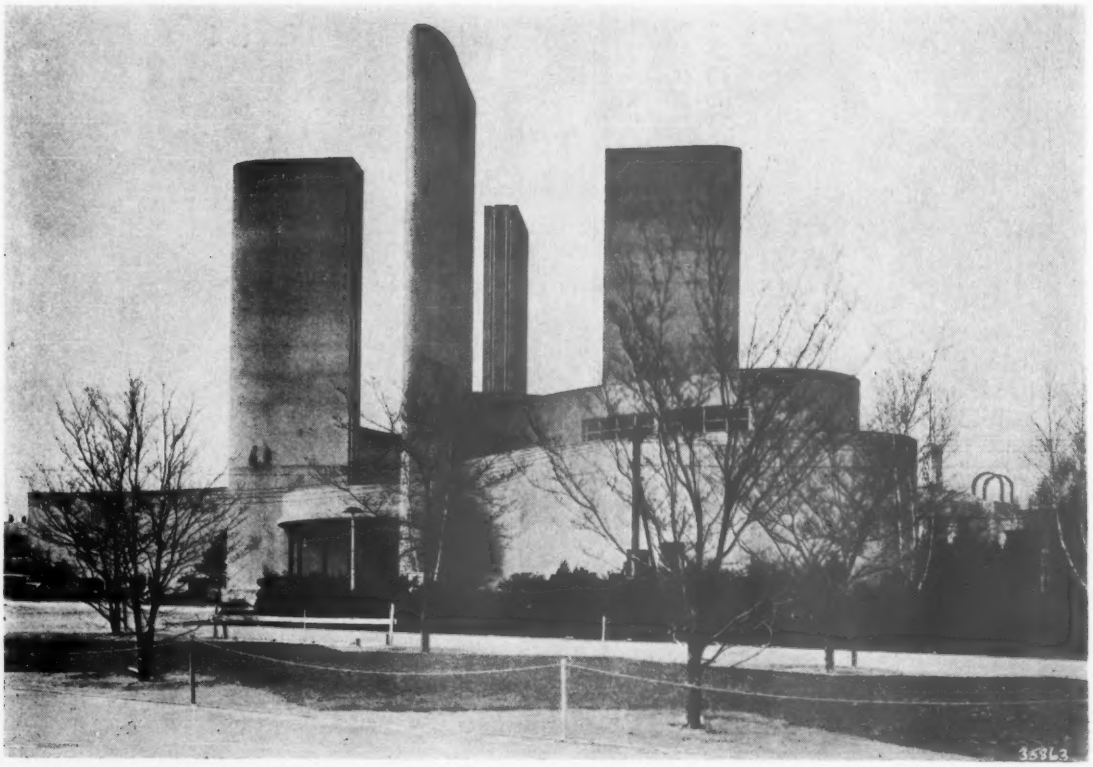
A part of the Television Demonstration in the RCA Exhibit





Glass Center Building and exhibition of the weaving of Fiberglas insulation material

Below is the Gas Industries Exhibit Building



Safeguarding Electric Utility Earnings

By H. P. Liversidge

President, Philadelphia Electric Company

An address before The Bond Club of Philadelphia, April 5, 1939

I PURPOSELY selected the announced title of this talk so as to indicate my personal belief that the future has better things in store for privately-owned electric utilities than have fallen to our lot for the past decade. If we could ignore the possibilities of a European disaster, I am confident that the outlook for our business—and other business, let us hope—holds considerably more promise than we currently might expect.

To be sure, in evaluating our future we cannot discount the continuing effects of economic and legislative action during the past 10 years. Nor can we disregard the permanent scars left by the unwarranted and ofttimes malicious attacks of those who, for the time at least, used utility-baiting as an emotional springboard for attempted leaps to popularity.

In many respects, our experiences in the utility field remind me of a story recently appearing in a widely-read weekly magazine. The contender for the light heavyweight championship, so the story ran, had a most inconsiderate second. The youngster was taking a pitiless pounding and in the first round one of his eyebrows was torn away by a booming punch. "Your round, Joe, by a mile; you're off to a good start," said the second. In the next round, the boy's nose was broken. "You're boxing rings around him," said the second when the boy wobbled back to his corner. He don't know where you're at. That's two straight rounds you win so far." In the third round, the youngster almost lost his left ear when he walked into a barrage. "You've got him, old fellow; he's groggy," said the second, as the boy flopped onto the stool. "Keep it up. You're way ahead."

With that the fighter arose from the stool, ducked through the ropes and started up the aisle to the dressing room. "Hey, where're you going?" screamed the second, running after him. "I'm quitting," said the fighter; "I'm quitting while I'm still ahead."

But we in this utility business are neither quitting nor running away from the job. The times are a challenge to private enterprise, and we have every reason to expect many years of satisfactory progress in a market we know to be far from saturation. A most hopeful sign of the times is a noticeable lessening of public interest in the multiplicity of so-called "corrective" measures. What a glorious field day they have had!

Limited time will hardly permit of giving factual evidence of a more favorable outlook for this business. For our present purpose, I ask you to take this for granted, bearing in mind that as we plan our future course, no matter what our hopes may be, there are some factors over which we will have little or no control and for which we must compensate in safeguarding our earnings. Among these are rate reductions ordered by public authority, continuation of the already excessive tax burden, greater restrictions on allowable rates of return, possible expansion of government competition, and the further advance of the public ownership idea—or even the nationalization of utilities.

All these things are in the lap of the gods. We can only trust that the sound commonsense of the American people will hold to the fundamental principle of private enterprise, which has enabled our industry to play such an important part in achieving for this country its present high standards of living.

We are fortunate that none of these so-called "corrective" measures has yet done irreparably serious damage to the soundness of the industry as a whole, no matter to what extent they may have been applied in specific cases. Our future success, therefore, insofar as it is within our control, rests primarily on the ability with which we direct our course. It must be a course that guarantees to our customers satisfactory service at the lowest possible cost, preserves fair wages to the employees, and at the same time earns for the investors a reasonable return on the fair value of the property used and useful in the business.

To acomplish this, it is self-evident that rates must make available to our customers the advantages accruing through greater use of electricity, from technological improvements and from managerial proficiency. Here, then, is one of our principal jobs for the future: to supply a steadily-increasing demand and, at the same time, to continue the downward trend of rates. The critical factor in such a program is this question of rates—the prices charged for electric service. Just because we have a past record of numerous voluntary reductions and have successfully met the many demands of regulatory bodies during the past few years, there is no reason whatever to assume that such reductions can continue indefinitely without impairing the financial stability of the industry. The moment return on investment fails to prove attractive, capital goes elsewhere, improvements and extensions lag, maintenance of property is curtailed and, in consequence, both customer and investor ultimately suffer.

The importance of this task—continuing rate reductions and at the same time safeguarding earnings—becomes evident when it is realized that we are today working on an extremely close margin. This margin could probably be regarded as safe were it not for the fact that sometime in the future—and let us hope it won't be soon—we must face another business depression. Unless we are foresighted, we may enter the next downward cycle in a much less favorable position financially than was the case in 1930. Theoretically, of course regulation of utility rates is expected to work both ways. Yet I have never been enthusiastic over the prospect of securing increased rates if the need arises when business and employment get to depression levels.

While we are on this subject, it might be well to refer to the limitation, either direct or implied, of the allowable rate of return placed upon us by regulatory bodies. From a casual observation, a limit like 6 per cent may appear to be reasonable. For the revenue of electric utilities is popularly thought to be little affected by the economic storms that much more drastically affect other businesses.

It is quite obvious, however, at least from a practical long-pull viewpoint, that maximum limits and average returns are often far different things. For when there are variations, they must all be on the minus side—never plus. Thus when a business recession comes

and the earnings fall below the fixed maximum, average earnings, if you are fortunate, will be somewhere between ½ and 1 per cent lower than the limit established.

Furthermore, under such a limitation, when the dip comes in the business cycle, a skilled management is likely to be at a disadvantage in comparison with an improvident one. At such times the less efficient operator has the hidden opportnuity of improvement. He can, if he so chooses, tighten up his performance to meet the situation. On the other hand, the efficient operator has no such leeway. He runs the danger of being penalized for his previous high standard of performance. Consequently, so long as a utility company is at all times limited in its earnings to a fair rate of return on the value of its property, a higher than average rate of return should be allowed during periods of good business. Thus it could counteract the effects of lower than average returns during periods of declining business.

We can only hope that regulatory bodies in the interest of both consumer and investor give more favorable consideration as time goes on to this increasingly important subject.

Our job of safeguarding earnings in the face of those factors beyond our control narrows very largely to the twin problems of electric rates and electric sales. Combined, these two elements of the business produce our operating revenue, and the relation of this revenue to the operating expenses and fixed charges, of course, determines the success of the enterprise. This may seem a trifle pedantic, yet in the pell-mell of forced rate reductions which have swept this country during the past few years, it has seemed, for a time at least, as if some of those responsible for such reductions had entirely overlooked these elementary facts. We are not likely to go very far wrong if we adhere strictly to the policy already stated: that rates of service should reflect the advantages accruing from greater use of electricty, from technological improvements and from managerial proficiency.

During recent years what has happened is that the cart has been placed before the horse and all too frequently rate reductions have been promulgated on the false assumption that increased use, as well as increased revenue, would automatically result. Nothing is further from the fact. Do housewives wash clothes more often, clean their houses more frequently, cook longer hours, refrigerate to a greater extent, or burn more light solely because electricity is cheaper? Of course not!—and the same thing holds true in every other classification of our business.

As a specific example of what really takes place when there is a rate reduction, let us take for illustration the experiences of the last downward revision here in the Philadelphia territory. This amounted to $1,650,000 and became effective March 1 of this year. The reduction was not the automatic signal for our customers of their own initiative to use more electricity. Let us see what did happen. On the date this rate reduction went into effect, the newspapers carried half-page advertisements announcing the reduction, and the news columns had carried considerable information about it during preceding days. Yet our retail salesmen, making slightly more than 100 calls on commercial customers that day, reported only three customers out of that 100 had heard anything whatever about a reduction. Similarly, some 10 days later an average of but three persons out of 10 among our residence customers had heard of it.

From this we can draw but one conclusion, namely, that the public generally was not particularly interested, even though it appreciated the cut. The truth of the matter is that this reduction was the starting signal for an intensive sales campaign involving practically every selling outlet in the entire district, and covering the entire range of electrical devices applicable to the home, the farm, the shop and the factory.

Let us try to visualize the magnitude of the job this reduction forced on us. For instance, it will be necessary for our domestic customers to purchase approximately $20,000,000 worth of electrical appliances in order that increased use may regain for us the loss of net income in this one class of business. In order that the rate of return on our present investment plus the new capital required to supply this additional service is maintained as it was before the reduction, it will be necessary that customers in all classes purchase and put into use approximately $72,000,000 worth of new equipment.

From this you can see how far from actuality is the popular idea that a rate reduction will automatically stimulate the public to the use of more electricity. What really happens is that after the knowledge of a rate reduction has sunk into the consciousness of customers through the medium of sales and publicity, they are more susceptible to the efforts of sales people who bring to their attention improved results that are possible through the use of new electrical equipment.

So long as the popular demand for greater electrical convenience can be translated into purchases of additional utilization apparatus—whether it be for the home, the shop or the factory—just so long carefully planned and properly timed rate reductions will develop more business without adversely affecting overall earnings.

The danger ahead lies in failure to recognize an obvious fact, that each year it becomes increasingly more difficult to sell an additional volume of business. Whether we admit it or not, sometime in the future we will approach a point of saturation where no matter what the reduction, nor how great the promotional efforts may be, there will be little, if any, compensating increase in use. While such a situation is indicated now in certain isolated sections of the TVA area, there is no immediate danger that the industry as a whole is nearing such a situation. In fact, our estimates clearly indicate that utilities should more than double their residential output alone during the next 12 or 15 years.

Certainly it is obvious, therefore, that increasing care must be exercised as future rate changes are considered. Proper balance must be maintained between the estimated amount of the reductions, on the one hand, and, on the other hand, the ability both of the consumer public to buy and of the industry to sell the additional equipment that will make up the consequent loss in net earnings. Furthermore, there must be a fair relation between rate reductions granted to residential and farm customers and those granted in the commercial and industrial classifications.

We never must lose sight of the fact that while reduced rates may increase revenue within certain limits and under certain conditions, at the same time operating costs, taxes and other current costs also increase. Increased business, likewise, requires greater investment to supply the service and thus adds to our fixed charges. If rate reductions impair our credit, then an unwise thing has been done and the utility is operating neither in the interests of the consumer nor the investor.

As time goes on it becomes of increas-

ing importance to the stability of the industry that greater and greater care be exercised in any changes to the form and balance of rate structures. It is fundamental that a rate structure must adhere as closely as practical to the costs of supplying the service throughout the entire range of its use. We are here dealing not only with a highly complex subject in itself, but the characteristics of the business also have undergone decided changes in the past 35 years. In consequence very definite changes have taken place in the nature of the cost elements.

Statistics indicate that for the industry as a whole the ratio of operating expenses to revenue is now 60 per cent of what it was some 35 years ago. However, the ratio of the sum of taxes, depreciation and return to operating revenue now averages approximately 65 per cent more than it was then. As an illustration of the cause of such major changes in the nature of utility costs, I might cite the average coal rate. By that I mean the amount of coal that has to be burned to produce a kilowatt-hour. It is now approximately 20 per cent of what it was 35 years ago. On the other hand, direct taxes in per cent of gross revenue are now four and one-half times the taxes of that earlier period.

It is axiomatic that the change in the relative magnitude of the major cost elements of electric service should be reflected accurately in the design of the rate structures for the various types of service if the industry is to retain its economic stability through all phases of future business cycles.

In dealing with this subject, greater care must be exercised that we are not swayed unduly by popular demands, which in most cases are based on a lack of correct information. The most common of these demands is that the top or highest priced steps of our domestic rates should be reduced so as to help those customers in the lower wage levels. As a matter of fact, records indicate that large numbers of small-use customers are not necessarily low wage earners. Many, many customers who make the fullest use of electric service are the families whose members do their own work and employ electric appliances to lighten their burdens. This statement may cause surprise. However, the fact is that this large group represents a substantial proportion of the liberal-use class which we strive to benefit. We believe this is the class that has earned the reduction and is most entitled to it, no matter what its economic or social position in the community may be.

Another little known fact is that nearly 50 per cent of our domestic customers do not use enough electricity to give the company an adequate return, under existing rates, on the investment required to supply them. And this figure, I think, you will find is better than average throughout the country. The best way to improve earnings on this class of business is to stimulate these customers to greater use of our service.

I am glad to report our company has shown excellent results in bringing about such increased use. Rate revisions which lower the price for more liberal use tend to induce it. Since 1930 we have built up our Residence Service sales from an average use of 576 kwhr to 957 kwhr in the year just ended—a 66 per cent increase. This increase, I am pleased to say, has been secured by rates which have been carefully priced to collect the full cost of increased consumption.

It is not sufficient that we carry on our business and continue the expansion of the property simply on an efficient management basis. As time goes on, it becomes of increasing importance that the pricing of our product be based on a most accurate knowledge of all the items that enter into total costs. From a popular standpoint, the cost of a kilowatt-hour is thought to be the same whether it supplies a single light or a 10,000-kwhr demand. This, however, is not the case. Characteristics of use, both daily and seasonally, the relation between the demand and use, the direct costs of production at various times of the day and year—all have a most important bearing on the question of the overall cost of service. It becomes apparent, therefore, that our rate structure should be such that it will accurately parallel the costs of the specific types of service under all conditions of use.

The importance of this general principle of rate applicability to type of use becomes clearer as we project our studies of future growth. In the case of the average domestic consumer, for instance, if his use should double the present average, it would be reasonable to assume that in times of business recession there would be a larger loss of his business than if his use has remained unchanged. Of even greater significance is the fact that the loss would first occur in the lower priced blocks. If rates are correctly constructed we should accordingly expect a minimum resulting loss in net earnings. On the other hand, the so-called minimum-use customer, will probably have continued all this time with little, if any, change in his consumption. Where rates have been incorrectly established it will most likely be found that there will be a loss in the profitable end of the business during a depression which will have the effect of increasing the proportion of unprofitable business that will remain fairly constant. Therefore, if we are to conserve the best interests of all, we must steadfastly refuse to adopt the uneconomic and dangerous expedients that have been so loudly called for in the past, and lower the price of the first block to a rate dangerously below the cost of service.

Our own company has taken the lead in the development of sounder rate structures. I feel confident that the results of our experiences have already proven of real value in such developments as we have inaugurated. I think they also have helped to focus national attention upon this increasingly important subject.

In conclusion it may be stated that basically, the electric light and power companies appear to be in an increasingly favorable position to meet the obligations imposed upon them by the orderly expansion of business. Managerial direction is on a higher plane and I believe more competent than at any time since the beginning of the industry. Technological advances of the past few years give more than reasonable assurance of greater things to come. Our present-day knowledge of customer requirements, characteristics of territory and technique of sales has reached a high degree of proficiency; and, what is of equally great importance, we are fortunate in having an extremely high standard of personnel.

We may draw the conclusion, therefore, that there is reasonable assurance that our future progress will be carried out with earnings adequately safeguarded. We must make certain, however, that our business is developed in an orderly manner, that the selling price of our service closely parallels costs and, lastly, that there will be a conservative approach to all new problems, thereby avoiding risks that from time to time in the past have leaped from the inexperienced minds of experimenters.

I believe we have the ability to safeguard the future economic stability of our industry, and I know, at the same

(*Continued on page* 272)

Simplified Standards for Distribution Transformers

Progress by E.E.I.-NEMA Joint Committee

HEREWITH is abstracted the report of progress of the E.E.I.-NEMA Joint Committee on Standards for Distribution Transformers as made by E.E.I. Chairman A. E. Silver, at the meeting of the Transmission and Distribution Committee in Chicago on May 4. It is printed here to inform utility engineers generally of the ideas being developed by the Joint Committee. The chairman solicits constructive comments at this formative stage. Any conclusions so far reached by the Joint Committee are held as tentative and subject to needed modifications as other features of distribution transformer design and arrangement are studied. Recommendations will not be forthcoming until the review is completed.

The Joint Committee has set as its first undertaking the range embracing single phase pole type units of 25 kv-a and under, and 15 kv and under, with two basic principles emphasized—

That the objective shall be a basic transformer embodying essential features, with additional devices treated as accessories.

That with suitable grouping of sizes, there shall be interchangeable mounting of all makes.

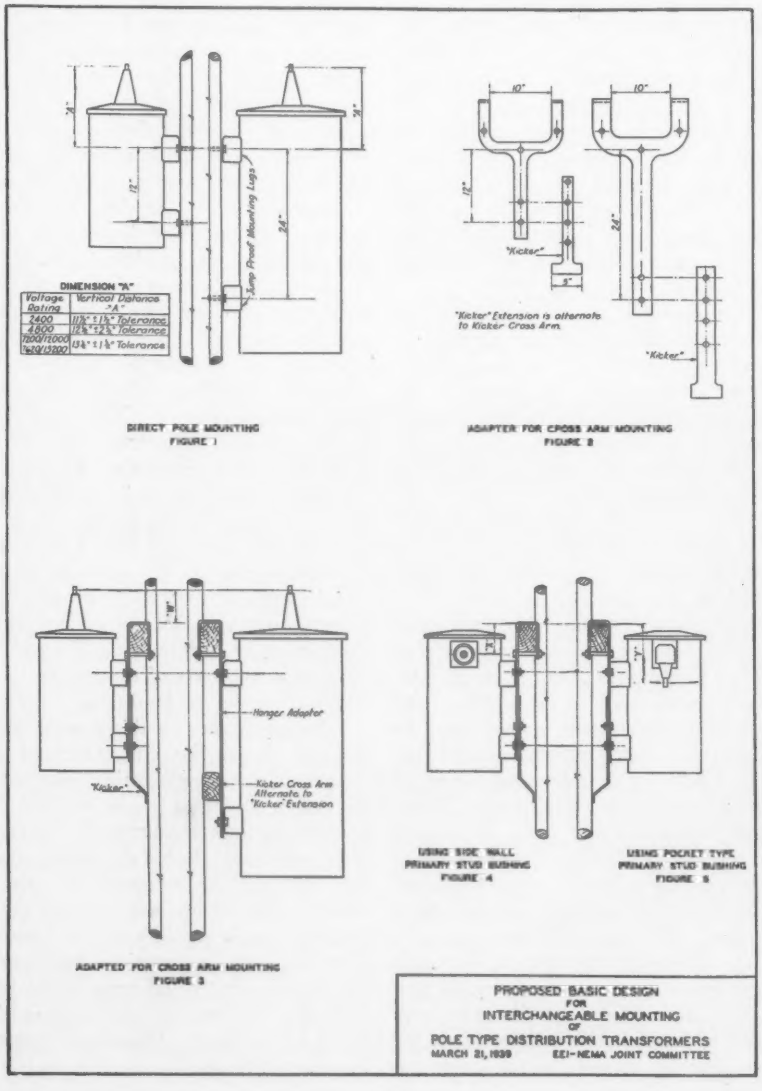
Since reviewing progress at the Transmission and Distribution Committee meeting in Rochester in February, the Joint Committee has held two meetings, March 9 and April 20, respectively. Both the NEMA and E.E.I. groups are keeping clearly in mind the Committee's established objectives, and satisfactory progress is being realized.

On the afternoon of the 2nd, at the Edgewater Beach Hotel, the E.E.I. members of the Joint Committee had the benefit of an informal discussion, with a group of interested utility engineers, on the problems and conclusions so far developed by the Joint Committee. Many constructive suggestions were obtained.

In its two most recent meetings, efforts of the Joint Committee were directed primarily to the matter of *interchangeable mounting for all makes of transformers*. E.E.I. Questionnaire Letter No. 3, of March 22, 1939, carried an outline description and diagram of a proposed mounting to the list of about 100 representative utility advisers. The response showed good acceptance of the ideas and brought constructive suggestions.

This proposed mounting utilizes the method applied in the so-called "farm type" transformer, brought out in the spring of 1935, and which has given good results in service. It embraces two mounting lugs, one above the other on the transformer tank, suitable for direct bolting to the pole.

With the mounting lugs as basic, there are provided as auxiliaries, an adapter for crossarm mounting and a "kicker" extension suitable for use in lieu of a kicker crossarm. In more detail, this interchangeable mounting provides: jump-proof features at both the mounting lugs and adapter at the crossarm; a mounting lug spacing of 12-in. for transformer sizes up to 10 kv inclusive, and 24-in. for 15 kv-a and over; drilling on 3-in. centers of the adapter and the kicker extension giving length adjustment to keep above the bottom of the tank and also flexibility in choosing vertical mounting position for the transformer; and the ready attachment of brackets for mounting auxiliary devices, if desired. The sketch, as circulated to the E.E.I. advisers, with Questionnaire Letter No. 3, shows the essential ideas of this mounting. (*Cont'd on page* 238)



DIRECT POLE MOUNTING
FIGURE 1

ADAPTER FOR CROSS ARM MOUNTING
FIGURE 2

ADAPTED FOR CROSS ARM MOUNTING
FIGURE 3

USING SIDE WALL PRIMARY STUD BUSHING
FIGURE 4

USING POCKET TYPE PRIMARY STUD BUSHING
FIGURE 5

The General Engineering Meeting at Chicago

By Alexander Maxwell
Director of Engineering, E.E.I.

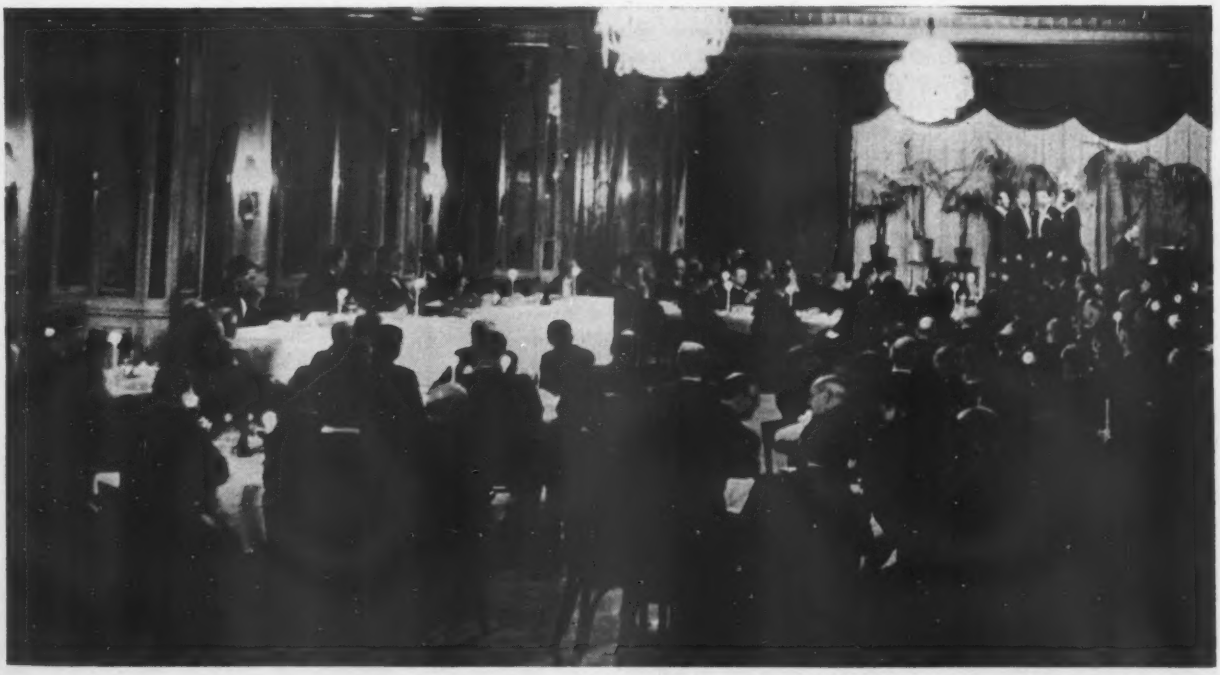
THE fifth general meeting of the five engineering committees of the Edison Electric Institute was held at the Edgewater Beach Hotel, Chicago, Ill., May 1 to 4 inclusive. This meeting proved to be the most outstanding of these sessions so far held under the auspices of the Institute, both as measured by the overall attendance and by the quality and diversity of reports and discussion affecting the construction and operation of the public utilities plant. In addition to the meetings of the regular committees of the Institute there were separate meetings of the various subcommittees, including those dealing with Meters and Services, Underground Methods and Accessories and Radio Interference, as well as other more or less informal groups dealing with more restricted or more transient subjects.

The sessions started with the meeting of the steering group of the Electrical Equipment Committee on Sunday evening, and concluded with the final session of the meeting of the Transmission and Distribution Committee on Thursday afternoon. The attendance at all of the sessions was unusually large and for several of the committees the attendance by a large number of members was equaled or excelled by the visitors who participated in the sessions. The total overall attendance at these meetings exceeded 300.

In accordance with the custom established several years ago, a joint dinner meeting was held on Tuesday evening. This meeting was attended by about 200. While this affair is intended primarily to be a get-together meeting since the members of the committees have little opportunity otherwise to meet each other, the occasion has been utilized in recent years for the presentation of an address upon some subject of importance to the industry and of general interest to all of the committees. On this occasion an address was presented by Mr. Nevin E. Funk, vice-president of the Philadelphia Electric Company. Mr. Funk spoke on the load requirements that might be expected by utilities due to unusual demands for supply such as those that might be brought about by rapid increases in industrial production. The address was a definite contribution to the knowledge of the fundamentals of this subject and proved of great interest to those in attendance. Mr. Funk's address is published in full in this issue of the BULLETIN.

These committee meetings cover in open and intimate discussion many of the various features of engineering connected with the operation as well as the design of the electric system. The Accident Prevention Committee studied in detail the method of pole top resuscitation which has been developed by the Duquesne Light Company and has been successfully practised by several other power companies. This discussion and accompanying moving picture proved of greatest interest to all attending this session. The Accident Prevention Committee also met jointly with both the Electrical Equipment Committee and the Transmission and Distribution Committee to discuss problems of mutual interest.

The range of subjects covered by the Electrical Equipment Committee com-



The Tuesday evening dinner proved enjoyable as well as instructive.

prises electrical equipment of various magnitudes and importance and includes such items as low voltage capacitors on customers' premises, the operation and testing of the new 3600-rpm hydrogen cooled generators, and domestic household electric ranges. Considerable time was devoted jointly with the Accident Prevention Committee in reviewing the features which could be incorporated in switchhouse design to prevent the possibility of accidents or of operating errors.

The Hydraulic Power Committee held three sessions on Wednesday in order to complete its crowded program in one day. In addition to discussing the engineering features of design and operation of hydro-electric plants considerable time was devoted to a thorough review and discussion of the latest means for predicting the total drainage of an area and the methods for handling the resulting flow so as to avoid the possibility of flood, and also to conserve the maximum amount of stored water for future prime power requirements.

The Prime Movers Committee reviewed the reports prepared by its subcommittees and made arrangements for the final editing of these reports for publication in the near future. In addition, the very interesting and worthwhile round table discussion, which has long been a feature of this committee's meetings, was held. Problems which have arisen in connection with the operation and maintenance of boiler plants and turbines were discussed and ideas on improvements interchanged.

The Transmission and Distribution Committee started its program on Wednesday morning with a review of the accomplishments of its subject committee on Underground Methods and Accessories. This was followed by detailed discussion of several recent developments in distribution design with improvements and modifications to obtain the maximum reliability of service at the minimum of cost. The Wednesday afternoon session, which was held jointly with the Accident Prevention Committee, analyzed in detail the cause of various accidents on overhead lines and showed how modifications and improvements might be made to reduce the probability of such occurrences. The Standards and Specifications group also reported substantial progress in its work of obtaining generally acceptable standards for certain types of equipment, which will result in simplification of stocking by the utilities as well as by the manufacturers and distributors of such equipment. This standardization, of course, has certain advantages in the normal operation of the electric system. However, at the time of emergencies such as the recent floods or the New England hurricane, standardization of equipment and methods shows outstanding advantages in aiding in obtaining equipment for the prompt restoration of service.

Accident Prevention Committee Meeting

L. M. Shadgett, Chairman

THE Spring Meeting of the Accident Prevention Committee was held at the Edgewater Beach Hotel, Chicago, Ill., May 1, 2, and 3, in coordination with the meetings of the Institute's several engineering committees.

Since the Accident Prevention Committee is a small, 16-man group, it properly and necessarily relies on other committees and bodies to cultivate accident prevention activities in their respective fields. With this policy in mind, arrangements had been made to devote two of the three afternoons to meeting in joint sessions with other committees.

Design of Substations for Accident Prevention

The Monday afternoon meeting was a joint session with the Institute's Electrical Equipment Committee, and consisted of a symposium on "The Design of Substations from the Point of View of Accident Prevention." Papers on various angles of this subject were presented by several members of each of the two committees, and were followed by open discussions of practical methods whereby substations and generating plants could be constructed and operated and maintained with less likelihood of injury to the personnel. Engineers and operating men are displaying more interest in this phase of their responsibilities than ever before. Most of them are, of course, keenly aware of the fact that the elimination of hazards to personnel goes hand in hand with plant reliability and the elimination of hazards to service.

The Tuesday morning and afternoon sessions were devoted to the consideration of progress reports on various subjects under more or less continual consideration by the committee as a whole. Subjects such as accident statistics; public safety; traffic hazards; employee training; line hazards; electric fences; rubber protective equipment for linemen; employee health; low voltage hazards; artificial resuscitation; first aid; etc., fall within this category.

Data compiled by the committee show that the accident experience of our particular industry was definitely better in 1938 than in 1937. Furthermore, tentative figures covering the experience of a number of typical operating companies during the first three or four months of 1939 indicate that a further material improvement is being made during the current year. These trends appear in all three of the usual criteria; that is, in days lost by employees, in lost-time accidents, and in fatalities.

The Wednesday morning session was reserved for the consideration of three topics of special interest to the committee and to the industry at this time. First was a motion picture and paper by Mr. R. M. Ruth of the Northern States Power Company on the subject of "Protective Equipment for High Voltage Lines." The high-light of this presentation was a description of that company's experience with a very ingenious and practical arrangement of wooden troughs and boxes designed for covering up circuits operating at potentials as high as 22,000 volts in the same general manner as rubber line hose and other rubber protective equipment is commonly used to cover up 2300 volt and 4000 volt circuits when men are working in close proximity to them.

Pole-Top Resuscitation

Next was a motion picture and presentation by Mr. E. W. Oesterreich of the Duquesne Light Company on the subject of "Pole-Top Resuscitation." A recent paper on this subject by Mr. Oesterreich was published in the March issue of the BULLETIN. In all known methods of artificial resuscitation, including the Schafer (prone-pressure)

method which is the one in most general use, any delay in starting the application of resuscitation materially reduces the likelihood of its success. The technique advocated by Mr. Oesterreich is designed to avoid part of the inevitable delay in cases where men receive electric shocks while working on poles, and the Duquesne Light Company's experience to date indicates that such a technique has much practical merit.

This pole-top method of resuscitation is not intended to conflict with or supersede the Schafer method, but is merely a means whereby resuscitation activities can be carried on during that vital period of time while arrangements are being made to lower the injured lineman safely to the ground. While this pole-top technique is not a difficult one to learn, the Accident Prevention Committee foresees some possibility of its doing more harm than good when attempted by men who have not received careful training and practice in its application. The results of a more extended experience with this pole-top method of resuscitation will be studied with great interest.

Next was a presentation on the subject of "Radio Aerial Problems" by Mr. R. A. Bloomsburg of the Niagara Hudson Power System. Mr. Bloomsburg's topic is of interest on account of the obvious risks taken by those who string radio aerials in close proximity to electric light wires. This problem is a more acute one in the comparatively densely populated residential sections. Fortunately, there seems to be a trend toward the more general use of vertical radio aerials, which are inherently much less hazardous from the point of view of possible accidental contact with electric light wires.

Joint Session with Transmission and Distribution Committee

The Wednesday afternoon meeting was a joint session with the Institute's Transmission and Distribution Committee. Mr. J. W. Anderson of the Philadelphia Electric Company presented a paper on the subject of "Directing Expenditures Toward Reducing Pole Line Accidents," which paper tended to show that much more good would be derived from spending additional money on training and educational work among line crew personnel than by spending it on improvemets to the physical properties.

Mr. W. A. Buchanan of the Appalachian Electric Power Company and past-chairman of the Accident Prevention Committee, presented a discussion on the "Cause and Location of Accidents" which pointed out those lines of work within the industry where the various groups of accidents occur.

The remainder of the joint session was spent in a discussion of these two papers, and of ways and means whereby distribution and transmission line engineers and operating men could help reduce the number of accidents being experienced by the class of workmen with whom they came in contact.

Following the conclusion of the Wednesday afternoon joint session, the Accident Prevention Committee adjoured until the time of its regular fall meeting.

Electrical Equipment Committee Meeting

H. L. Wallau, Chairman

THE spring meeting of the Electrical Equipment Committee was held at Chicago, May 1 and 2, in conjunction with the other engineering committees of the institute. Twenty-three members of the committee were present and about 33 visitors attended the open session of the meeting.

The session on Monday morning was devoted to a discussion of apparatus troubles, oil fire report, and as usual, was confined to members of the committee and representatives of member companies. Mr. Eales presented a paper giving full details of the San Diego switchhouse failure and the resulting power system shut-down. This report, as has been the case with other similar accidents, was thoroughly reviewed by the committee and discussed. As a result of this discussion complete information is available to all members of the committee as to the exact cause of this shut-down, and the lessons to be learned from it so as to avoid other similar ocurrences. The detailed discussion of failures have proven of immense value in transmitting the experience of one company to all others, and has resulted in many worth-while and substantial improvements in design and operating practice, looking forward to preventing other similar occurrences.

The Monday afternoon session was a joint meeting with the Accident Prevention Committee, where subjects of mutual interest to these two committees were discussed. Mr. Benson presented a report of the Storage Battery Subject Committee, pointing out the factors necessary to be taken into consideration for the most satisfactory and efficient installation and operation of storage batteries. This report also pointed out the safety precautions necessary to avoid injury to personnel working in and around large storage batteries.

Mr. Eales makes his point.

Mr. Field's report on Reclosing of Circuit Breakers gave the results of replies received from 28 operating companies in the United States, 10 in Canada and one in Mexico. The majority of the companies reported that they restored service immediately to manually controlled lines that had tripped out automatically, and without making any tests or patrolling of the line. This, of course, also applies in the case of automatically reclosed lines. Exceptions were reported in cases where "hot-wire" crews were working on the line, or where multiple or loop lines were installed, no service being interrupted. There have been very few cases of trouble with customers' equipment, and where such has occurred the power company has assisted the customer in fixing up or applying undervoltage releases and overload protection

in order to insure the best possible service.

The symposium of Design of Substations from the Point of View of Accident Prevention was contributed to by a large number of the members of the committee. Many features are installed primarily to insure safety to personnel and to minimize the possibility of operating errors. These range from relatively simple steps, such as painted strips on cell structures, guard rails, temporary working platforms to elaborate mechanical or electrical interlocking systems. Even with all of these precautions, certain accidents still occur due to human error or misunderstanding. However, continuous effort is made to hold them to a minimum.

Mr. Stokes presented a very interesting discussion of the terms to be used in connection with utilization voltage. Such terms as service voltage, customer voltage, average voltage, minimum voltage, maximum voltage, have been used without universally acceptable definitions. The committee is proceeding to establish universally acceptable definitions for these terms.

Mr. Couts presented a paper showing some of the difficulties that have been encountered in connection with the installation of capacitors on customers' premises. These difficulties have been confined largely to low voltage appliances and are generally due to local resonance conditions or overvoltage conditions at times of light load.

Mr. Forbes and Mr. Hentz listen. Mr. Conwell inspects his camera.

On behalf of the Meter and Service Committee Mr. Craig reported that the manuscript for the new Metermen's Handbook was practically complete and should be in the hands of the printer within the next month. A revised draft of the Summary of Public Utility Commission Rules is being finally reviewed by the committee. Copies of this draft are available to member companies.

Messrs. Jones of General Electric Company, Laffoon of the Westinghouse Company, and Mortensen of the Allis-Chalmers Manufacturing Company, presented a thorough discussion of the factors involved in the short-circuit tests of generators, particularly relating to the new 3600 rpm machines. As a result of this discussion it was concluded that the present ASA rule relating to short-circuit testing needs some revision, and steps are being taken to have these changes made by the proper committee.

Mr. Robinson presented a discussion of the design of a small 110 kv substation where every effort was made to minimize both the overall cost and the actual cash outlay. A paper describing this substation is published in this issue of the BULLETIN.

Mr. Webb presented a Progress Report on the work of the Subject Committee on Generator Insulation. He also presented a final report describing the practice of the various companies represented on the committee in the routine maintenance and testing of generators.

Hydraulic Power Committee Meeting

E. B. Strowger, Chairman

AT the meeting of the Hydraulic Power Committee held in Chicago, May 3 and 4, a report by Mr. Albion Davis on the work of the Governor Subcommittee indicated that some progress has been made in the study of system governing although not many companies have as yet supplied the committee with data disclosing the characteristics of governors in relation to system conditions such as was presented by Mr. Collins of the Washington Water Power Company and Mr. Davis of the Union Electric Company of Missouri at the December, 1938, meeting in New York. It was pointed out that governors may be responsible for the short period swings of speed on an isolated system and swings of tie line loading on an interconnected system. The importance of analyzing the short period swings in system speed in relation to tie line load changes is therefore apparent.

Mr. Hammond described the operation of the Georgia Power system in regulating frequency. He pointed out that several large plants were chosen to control the load over their principal tie line and two or three large units were put on system frequency control and after this was done the oscillations in tie line loading were greatly reduced.

Mr. Davis submitted a set of specifications for a governor including a definition of sensitivity, in which provision is made for adjustment of governor speed droop from the switchboard ranging from 0 to 6 per cent, and provision for synchronizing at low frequency (say 42 cycles) in order to operate during emergency conditions.

Mr. W. P. Creager discussed the method now quite generally used for computing flood flows—the unit hydrograph method. This method is used by some engineers instead of the old probability methods especially where reservoirs are involved. The discussion centered about the margin of safety which should be allowed on top of the hypothetical storm superimposed on the drainage area. It was pointed out that at the present time this margin varies from about 10 to 80 per cent.

Mr. Merriam mentioned the work being done on two small reservoirs on

the Upper Susquehanna drainage area, *i. e.*, the Arkport Dam on the Canisteo River and the Whitney Point Dam on the Otseltic River. There followed a general discussion on single purpose and dual purpose reservoirs. It was pointed out that depending upon the soundness of the assumptions made, one could get most any answer as to the economics of the project, but such answers do not reduce the project cost which the taxpayer some day has to pay. It was commented that some flood control projects are being built on sentiment with no consideration given to the economics involved. It was pointed out that in the case of the TVA flood control projects, the Tennessee River will be caused to flood 666,000 acres of land permanently whereas before these projects were built 750,000 acres were flooded occasionally. It is very difficult to justify Flood Control projects where the land involved is mostly rural and in general the only chance of justification is on the basis of protecting industrial lands in cities.

The suggestion was made that if a river has a definite flood season, the application of the flood level required for Flood Control can be limited to a certain time during the year thus releasing volume for power development during the rest of the year. It is reported that this is being done at Norris. However, some engineers do not recommend this procedure. In general complete flood protection is not economic. For instance, the Army Engineers report that a 30 ft. dike would be necessary around the City of Chattanooga after the TVA program is completed if complete protection is to be effected.

Mr. McChesney of the Rochester Gas & Electric Company gave an illustrated talk on the tunnel test made by this company to determine the best method of repairing their 20 ft tunnel at Station No. 5 at Rochester, New York. The tunnel lining and part of the rock foundation had been eroded just downstream from the point where the vertical tunnel shaft make a 90° bend into the horizontal tunnel section, and the model tests described and illustrated showed several alternative methods of repair which would effect reduced loss of head and a satisfactory velocity distribution. Mr. McChesney also exhibited an interesting set of moving pictures showing the model tests of the Mt. Morris Dam spillway.

Transmission and Distribution Committee Meeting

H. P. Seelye, Chairman

A LARGE attendance and a full program featured the two-day meeting of the Transmission and Distribution Committee held at the Edgewater Beach Hotel, Chicago, May 3 and 4. As mentioned elsewhere, this meeting was a part of the Group Meetings of the engineering committees. The regular sessions of the T & D Committee were preceded by an all day meeting on May 2 of the Subject Committee on Underground Methods and Accessories under the chairmanship of J. A. Brooks. In addition to this, several other groups held informal conferences and meetings for the purpose of discussing the status and progress of their respective assignments and to decide upon plans for future work.

Many of its members and guests attended the Dinner Meeting of all the committees on the evening of May 2, which was presided over by Mr. W. A. Buchanan, district manager, Appalachian Electric Power Company, and at which Mr. N. E. Funk, vice-president of the Philadelphia Electric Company, was the principal speaker.

The first session of this meeting was devoted to reports, papers and discussions by the Underground and Transmission groups, presided over by Messrs. C. W. Franklin and Merrill DeMerit respectively. Under Mr. Franklin's portion of this program were presented reports and papers as follows:

(a) Report of the Meeting of the Underground Methods and Accessories Subject Committee, held on May 2, by J. A. Brooks.

(b) A Combined Overhead and Underground Network in Detroit, by Harold Cole, The Detroit Edison Co.

(c) The Use of Cables Insulated with Corona-Resisting Compounds for Pole Riser Service, by T. J. Brosnan, Buffalo Niagara Electric Corp.

(d) Cable Fault Location Through Vibration Caused by Application of Steep-Fronted Wave, by L. E. Kline and C. J. Shuttleworth, The Detroit Edison Co.

(e) Neutral Conductors for Underground Distribution Circuits, by W. R. Bullard, Ebasco Services, Inc.

One paper and one report were presented under Mr. DeMerit's part of this session as follows:

(a) Some Parts that Transmission Lines Play in the Operation of Bulk Power Supply Systems, by Merrill DeMerit, West Penn Power Co.

(b) Operation Report of Protective Gaps on Transmission Lines for 1938, by D. M. Bunn, Northern States Power Co.

The afternoon session on May 3 was a joint meeting with the Accident Prevention Committee. Mr. J. W. Anderson, of the Philadelphia Electric Company, presented a paper on Directing Expenditures Toward Reducing Pole Line Accidents, and Mr. W. A. Buchanan, former chairman of the Accident Prevention Committee, presented a summary of data that had been collected within the industry on the Cause and Location of Accidents. In addition to these, there was held a Round Table Discussion on specific problems with which both these committees are concerned and which can be solved best through cooperative consideration and study.

The forenoon session on May 4 was taken up by summary reports on projects under the Plant Coordination Group, Mr. W. F. Davidson, Chairman, and the Overhead Distribution Group, under the chairmanship of Mr. W. F. Nimmo.

Reports on the Plant Coordination subjects were mainly abstracts of reports that have been prepared cooperatively with the Bell Telephone System and presented as information to members of the committee. The subjects reported on were: Coordination of Rural Power and Telephone Lines; Bonding of Telephone Cables to Power Neutrals and Street Lighting Brackets; Sodium Vapor Lighting; and the Size and Strength of Wood Poles in Joint Use Construction.

In addition to these, Mr. M. D. Hooven discussed the work that is being done on radio interference and stressed the importance of this subject to power companies generally. He told of the development of a new instrument for measuring the noise level of interference to radio reception and urged power companies to secure one of these instruments

through the use of which they could ascertain the true conditions of radio interference in their respective territories, and locate the various causes. Full and complete information on this problem and the instrument referred to above may be obtained by addressing M. D. Hooven, Public Service Electric & Gas Co., 80 Park Place, Newark, N. J.

There was also presented at this session a report on the status of an ASA standardization project that has received the attention of this committee during the past several years dealing with manhole frames and covers. On numerous occasions this matter has been discussed in the Transmission and Distribution Committee and in the Undeground Systems Committee of the former National Electric Light Association. On each occasion there has been a preponderance of opinion recommending against the endorsement of this proposed standard and at this meeting definite action was taken which confirmed the opinion expressed on the previous occasions when this subject had been under committee discussion and consideration.

The latter part of this session was in charge of the Overhead Distribution Group, while discussions were held on Bare Wire Vs. Covered Wire for Aerial Construction, Burn-Off Characteristics of Conductors, and the current revision of the National Electrical Safety Code.

The afternoon session was given over to the Standards and Specifications Group, E. V. Sayles, Chairman, and a continuation of the program of the Overhead Distribution Group under W. F. Nimmo. Under the standardization work discussed, Mr. A. E. Silver told what has been done in the standardization of distribution transformers by a joint committee of the National Electrical Manufacturers Association and the Edison Electric Institute.

Mr. Nimmo, Mr. Bund and Mr. Seelye discuss T & D Committee affairs.

Mr. L. G. Smith informed the committee of the progress that has been made in revising the wood crossarm specifications prepared several years ago by the Overhead Systems Committee of the former NELA. Included in this part of the program was the presentation of a paper by Mr. J. A. Vaughan of the Southern Wood Preserving Co. on the Moisture Content in Poles as Related to Conditioning and Treatment.

During the continuation of the program of the Overhead Distribution Group, papers were presented as follows:

(a) Conductor Vibration and Fatigue, by L. C. Peskin, American Steel & Wire Co.
(b) Operating Experience with Capacitors, by M. C. Miller, Ebasco Services, Inc.
(c) Transformer Loading by the Statistical Method, by M. T. Crawford, Puget Sound Power & Light Co.

This is the last meeting under Mr. Seelye, who has served as Chairman of the Transmission and Distribution Committee during the past two years. The successor to Mr. Seelye has not yet been appointed.

The next meeting of the committee will be held during the early part of next October.

Prime Movers Committee Meeting

W. E. Caldwell, Chairman

THE fourth meeting of the Prime Movers Committee for the year 1938-1939 was held May 1 and 2 at the Edgewater Beach Hotel in Chicago.

Mr. Sabin Crocker reported on the attitude of ASA Subgroup 6 concerning the Prime Movers Committee suggestion to standardize the side outlet dimension of welding tees. He also discussed with the committee the matter of standardizing socket welding fittings. The committee agreed that an effort should be made along this line.

Mr. Orrok reported for Mr. Engle on the progress of the work of the Boiler Subcommittee.

The Chemistry Subcommittee's report is now in the hands of their Editing Committee. Mr. Fellows outlined, briefly, the principal subjects covered by the report.

Mr. Muir reported on the progress of the Combustion Subcommittee work and urged the members to provide more complete answers to the questions sent out by Mr. Luce. The various divisions of the Combustion report were outlined by Messrs. Drabelle, Williamson and Stiff.

Mr. Boetcher outlined the developments in the work of the Metallurgical Subcommittee and explained the difficulties in collecting the data required.

The special committee appointed at the last meeting to recommend a basis of design for feedwater piping presented its conclusions. This committee consisted of Messrs. Boetcher, Daniels and Hopping. The recommendations were accepted by vote of the main committee for transmission to the appropriate ASA subgroup.

Mr. Drabelle announced that no formal report would be issued this year by the Oil and Gas Engine Committee but that such data as it had collected would be sent the Commercial Subcommittee of the E. E. I. on Power and Heating, to use in their report.

The progress of the Turbine Subcommittee report was presented by Mr. Crofts. All sections are now practically completed. Mr. Daniels briefed for the

(*Continued on page 264*)

Factors Affecting Generating Capacity

By N. E. Funk

Vice-President, Philadelphia Electric Company

Address before the Engineering Committees of Edison Electric Institute, Chicago, May 2, 1939

PREVIOUS to 1929, predictions of future generating capacity requirements in any individual system could be quite readily made by relying on the characteristics of past performance. Since that year, however, there have been no definite guide posts which can be depended upon with any security. During the first few years of the depression, the tendency was to be too *optimistic* in predicting the future, and in the later years, too *pessimistic*, the net result, however, being that in the main, sufficient capacity has been installed to take care of the present-day needs.

From some sources, estimates of the required increase in national capacity have been made, based primarily upon assumptions of past performances of annual kwhr per kw of installed capacity. Unless this factor is analyzed with considerable care, the arithmetical result obtained may be quite misleading. I think it may be of some interest to consider for a few moments a simple analysis that can be made.

Attention is drawn to Fig. 1, in which the years from 1920 to 1938 have been plotted as abscissa, and the annual kwhr per kw of generating capacity plotted as ordinates. On these coordinates have been plotted the domestic, the small commercial light and power, industrial, large light and power and miscellaneous other uses, and the total, all on the basis of the total kwhr of each class divided by the total generating capacity in kw.

Round figures only will be used in the discussion.

In the year 1920 the total kwhr per kw of capacity was 3200. In 1921 (which you will recall was a depression year) this figure fell to 2700, thereafter recovering and varying between 2800 and 3000 up to 1929; the factor then fell to 2300 in 1932, and rose again to the highest figure which ever occurred in the industry; namely, 3300 in 1937, and then fell to 3000 in 1938.

The tendency has been to consider that the improvement in this factor was primarily due to an increase in industrial applications and better load factor, in general, in industry. A different picture,

MR. FUNK

however, is obtained if the kwhr per kw are segregated into, say, three major classes: (1) domestic (including farms), (2) small commercial light and power, and (3) industrial large commercial light and power and other miscellaneous uses. I wish to caution you that these figures do not indicate the hours' use of kw of capacity for any given type of service, but merely the subdivision of the total kwhr generated for the supply of different types of service per kw of capacity.

When this is done, the factors obtained indicate that in 1920 1 kw of capacity supplied 300 kwhr to domestic service, 400 kwhr for small light and power, and 2400 kwhr for other services. The domestic and small commercial gradually increased from this figure to 450 and 550, respectively, in the year 1929, while the industrial factor dropped from 2400 to 2000 in 1921, and rose to 2200 in 1923, and then fell to an average of 2000 for all the years from 1923 to 1929 inclusive, the variation being of the order of 50 kwhr. In 1929 the factor for industrial power and other uses decreased very rapidly, reaching the bottom in 1932 of 1400, and from this year increasing gradually to an average of approximately 2000 for the years 1936 and 1937, and then dropping to 1700 in 1938. The domestic continued to increase continually after 1929 to 1938, when the factor was almost 700 kwhr, with the single exception of a very slight decrease from 1932 to 1933. The factor for small commercial light and power decreased slowly from 1929 to 1933, at which time it had dropped to approximately the same figure as 1920; namely, 400, and then rose to a figure of 600 in 1938.

I think it is interesting to note from these figures that while the average for the total kwhr per kw of installed capacity remained practically constant around 2900 during the years previous to 1929 and rose to a materially higher average figure of 3200 for the years 1936 and 1937, that the industrial power, except for the years 1920 and 1923, remained practically at 2000 kwhr for the same years, and that during the same period there was a continued growth in the domestic and small commercial kwhr. This would seem to indicate that, in general, the improvement in kwhr produced per kw of installed capacity cannot be attributed to the larger industrial loads, but rather to the change in character of the domestic and small commercial loads caused by a material increase in use of energy in both the homes and small business enterprises, primarily at periods off the peak of these types of load.

Of course, more intelligent discussion could be presented if the kwhr per kw of peak load were readily available, since the factor of kwhr per kw of capacity does not indicate the extent to which equipment is loaded during the maximum demand period.

It is evident that it is fallacious to use any method of determining the required increase in national capacity based upon the national growth of energy generated or energy sold without a detailed study of the class of load in which increased use of energy has occurred, the effect of this increased use upon the shape of that particular load class and the effect of the change in the class load shape on the system load as a whole.

In passing, however, it might be interesting to note that while the total sales

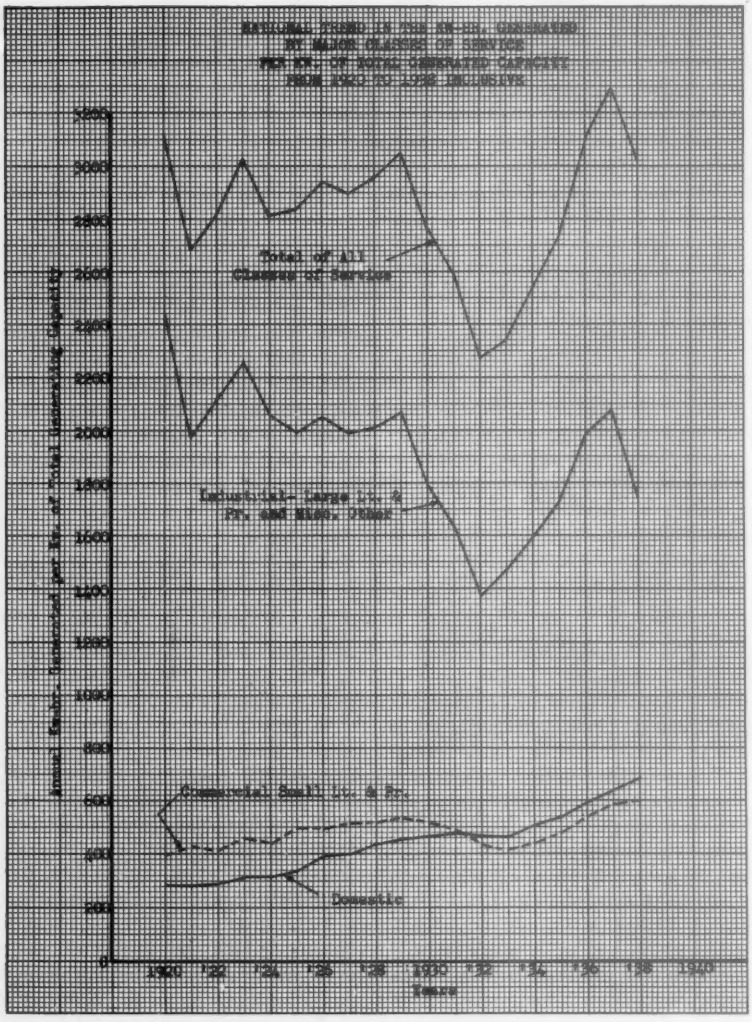


Fig. 1—National Trend in Kwhr Generated by Major Classes of Service

of energy to the domestic class of service increased more than seven times from 1920 to 1938, the kwhr of this class per kw of total capacity increased about 2.3 times. This is merely another method of expressing information already well known to practically everyone in the industry; namely, that the tremendous increase in the use of domestic appliances has materially altered the shape of the domestic load, and that a vast part of the increased domestic kwhr are used at periods other than peak of the domestic load.

The preceding discussion will immediately bring to our minds the effect that the variation in the load factor of the individual customers may have upon the shape of the load and the diversity. That we may be discussing factors of the same order, I will use the term "coincidence factor" as representing the ratio of the summated demands of a class to the sum of individual demands within that class. By the definition, the coincidence factor will be 100 per cent when all the demands of the individual customers are concurrent as to time, and will be a minimum when there is the maximum divergence in time of individual demands.

Suppose we lay out our curve in Fig. 2 by plotting load factor of the individual customers from 0 to 100 per cent as abscissa, and group coincidence factor in per cent from 0 to 100 per cent as ordinates. Now, we construct a right angle triangle with its apex at the origin, its base along a horizontal line passing through 100 per cent coincidence factor, its hypotenuse drawn from the origin to the intersection of 100 per cent load factor, and 100 per cent coincidence factor. This triangle is upside down on our graph. The area of this triangle represents all of the possible locations of functional relations between load factor and coincidence factor. That is, for a given load factor the coincidence factor cannot be less than the load factor, and it cannot be greater than 100 per cent. That the coincidence factor cannot be less than the load factor is subject to rigid mathematical proof for any given load factor. However, I believe this fact can be established by a less complex demonstration than the mathematical proof. Assume two continuous loads of one kw each; one operating from 12 o'clock midnight to 12 noon, and the other 12 o'clock noon to midnight, with no overlapping of the loads. Obviously, the total demand for the day with these two loads is one kw. The sum of the individual demands is two. The coincidence factor is therefore 50 per cent. The load factor of each load for the day is also 50 per cent. One kw x 12 hr x 100 ÷ 24 hr x one kw. Similarly, if these one kw loads of the same type are operated in 4-hr shifts, the maximum demand produced in a day would still be one kw, the coincidence factor would be over six (16.66 per cent) per cent, and the load factor of each individual load would be likewise one over six (16.66 per cent) per cent (1 x 4 x 100 ÷ 24). That the coincidence factor cannot be greater than 100 per cent is established by the definition of coincidence factor.

The first impression might be that for any given load factor the coincidence factor could vary over a wide range, particularly at low load factors such as 30 per cent, where it might easily theoretically vary between 30 per cent and 100 per cent, depending upon whether the times of demand were quite divergent or concurrent.

Numerous tests made of the domestic class of service and the retail and wholesale commercial and industrial light and power class seem to indicate, however, that there is a very marked and close relation between load factor and coincidence factor. For the commercial and industrial load, this curve (Fig. 2), originating at the origin, rises quite rapidly and practically on a straight line to a point where the coincidence factor is 75 per cent when the load factor is 20 per cent. From this point, the curve bends sharply to the right, reaching a coincidence factor value of 84 per cent, at approximately 40 per cent load factor, thereafter remaining practically constant until the load factor has increased to a value greater than 75 per cent, when the coincidence factor again rises sharply

to become tangent to the 45 deg line at approximately 90 per cent load factor. Admittedly, the shape of the curve from an 80 per cent load factor on is more of academic interest than practical.

The surprising thing to me, at least, is that the coincidence factor for the domestic load follows practically the same curve, except that a 75 per cent coincidence factor is not reached until approximately 30 per cent load factor, as compared to 20 per cent for the previous group of tests, and does not become a constant value until approximately 50 per cent load factor, at which it also reaches 84 per cent coincidence factor. The performance of the domestic load curve above 50 per cent load factor, however, would be one of conjecturing rather than actual test figures, because of the fact that domestic installations above this load factor are not available for test.

At first glance it does not seem reasonable that chance, alone, could produce such constant values of coincidence factors over so wide a range of load factor, and I believe a little thought will indicate that it is not a coincidence with these curves.

If we assume a continuous load of one shift operation for a 40-hr week, and no load at all during the other hours, the maximum load factor that could exist would be 24 per cent. On a two-shift basis it would be 48 per cent, on a three-shift basis 72 per cent, and for continuous operation 100 per cent. However, practically no industrial loads can maintain an absolutely continuous demand, and for this reason it is quite probable that we will find the load factors more on the order of the following figures:

One-shift Basis—20 per cent.

Two-shift Basis—40 per cent.

Three-shift Basis—60 per cent.

Continuous Basis—Approximately 80 per cent.

When it is recognized that the increase in load factor is obtained during other hours of the day, with an increasing number of shifts, it is not surprising that the coincidence factor does not materially vary over a wide range of load factor. I think it is important that this relation of coincidence factor and load factor should be kept in mind for any studies relating to the increased capacity required by the addition of large blocks of high load factor loads.

I should like to suggest to you some of the ideas that the previous discussion brings to me:

1—The ratio of the coincidence maximum demand on the day of the system peak of the industrial customers to the sum of their individual maximum yearly demands need not be greater for material additions of high load factor loads than under normal conditions of operation, providing the monthly load factors of individual customers under normal conditions of operation exceed 30 per cent, and that the additional high load factor loads do not individually exceed 75 per cent or 85 per cent load factor. If the load factor of individual customers under normal conditions is less than 30 per cent but not less than 20 per cent, there will be a slight increase in the coincidence factor, but the increased factor will remain practically the same, whether the individual load factors increase only to 40 per cent or to 80 per cent.

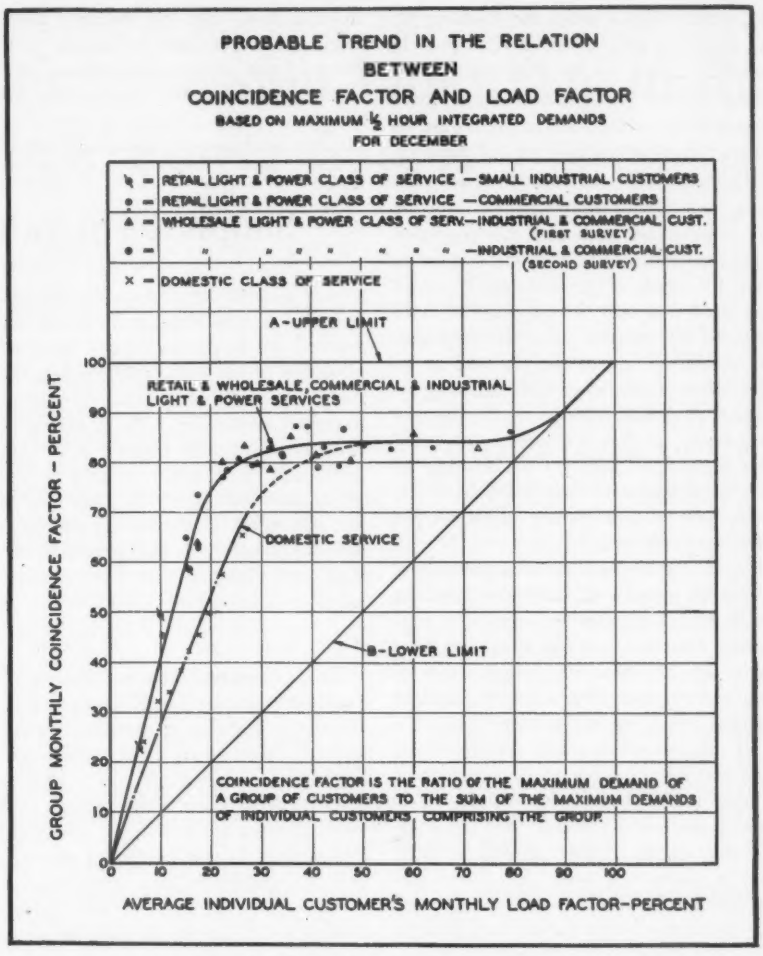

PROBABLE TREND IN THE RELATION
BETWEEN
COINCIDENCE FACTOR AND LOAD FACTOR
BASED ON MAXIMUM ½ HOUR INTEGRATED DEMANDS
FOR DECEMBER
½ = RETAIL LIGHT & POWER CLASS OF SERVICE —SMALL INDUSTRIAL CUSTOMERS
○ = RETAIL LIGHT & POWER CLASS OF SERVICE —COMMERCIAL CUSTOMERS
△ = WHOLESALE LIGHT & POWER CLASS OF SERV.—INDUSTRIAL & COMMERCIAL CUST. (FIRST SURVEY)
● = " " " " " " " " —INDUSTRIAL & COMMERCIAL CUST. (SECOND SURVEY)
× = DOMESTIC CLASS OF SERVICE
A-UPPER LIMIT
RETAIL & WHOLESALE, COMMERCIAL & INDUSTRIAL LIGHT & POWER SERVICES
DOMESTIC SERVICE
B-LOWER LIMIT
COINCIDENCE FACTOR IS THE RATIO OF THE MAXIMUM DEMAND OF A GROUP OF CUSTOMERS TO THE SUM OF THE MAXIMUM DEMANDS OF INDIVIDUAL CUSTOMERS COMPRISING THE GROUP.
GROUP MONTHLY COINCIDENCE FACTOR - PERCENT
0 10 20 30 40 50 60 70 80 90 100
AVERAGE INDIVIDUAL CUSTOMER'S MONTHLY LOAD FACTOR-PERCENT

Fig. 2—Probable Trend in the Relation between Coincidence Factor and Load Factor

NOTE: This curve was first presented by Mr. Constantine Bary of the Philadelphia Electric Company in a paper entitled "Economic Significance of Load Characteristics as Applied to Modern Electric Service" at the 53rd Annual Meeting of the Association of Edison Illuminating Companies, January 17-21, 1938.

2—Should material additions be made of this type of load, but the individual load factors be maintained at the normal load factor of the existing individual customers, then it can be expected that the capacity required will bear somewhat the same relation to the capacity now required for the industrial load as the added load bears to the existing load.

3—There is no fundamental relation between the non-industrial load and the industrial load. True, it can be argued that if the load factor of the industrial load is increased by the application of three shifts, additional labor is required, and this additional labor, of necessity, must be housed and otherwise supplied with the necessities of life, which will be the cause of increase in both the domestic and commercial load requirements. Practically, however, a large increase in additional shifts could not be immediately followed with the necessary hous-

ing, which would mean the doubling up of families and material increase in boarders taken in by families or the transportation of workers from more distant housing facilities to the industrial center, none of which would immediately materially increase the domestic load, and would only slightly increase the commercial load, and this condition would maintain until building caught up with the needs of the community, or, if this need was only a temporary one occasioned by unusual industrial activities, the possibility is that there would be no real effort made to provide housing facilities to completely satisfy the temporary needs, so that it cannot be expected that a material addition of the type of industrial load referred to would necessarily have a concomitant effect on the other types of loads.

4—The analysis of the change in character and growth of load occasioned by the installation of various classes of utilization facilities and the effect of these variations on the total system capacity requirements necessitates a very complete analysis requiring the procurement of a large amount of data and application of time and intense study to the problem. I believe under today's conditions it is more important than ever that the various units of the industry should be thoroughly acquainted with the theoretical considerations involved in this study, and have available data on their own systems to permit them to intelligently and correctly guide the prediction of the possible effect of various load conditions on their system capacity.

The problem of adding generating capacity is not one alone of determining the time and amount of capacity required by any individual system, but is very intimately related to the turbine production capacity of the manufacturers which, in turn, is not a function alone of the physical facilities in the hands of the manufacturer, but essentially one in which skilled labor plays an extremely important part. This means that low production levels cannot be stepped up overnight, but require a materially greater period of time, and thus sufficient foresight must be exercised by the purchasers of this equipment in determining their needs, so that unexpected difficulties will not arise in obtaining equipment in time to meet the expected loads. There has been no time, at least within my experience, in the history of the industry, in which the engineers have had more responsibilities resting on their shoulders than at present, and it is a very helpful thing for the industry that its engineers can gather in groups as they have in the various committees at this Chicago meeting to discuss the many problems which arise, and to exchange ideas as to their possible correct solution.

I wish to congratulate the committees on the splendid work they have done in the past, and know from the existing personnel of these committees, that this work is going to be continued into the future.

Simplified Standards for Transformers

(*Continued from page* 228)

The Committee plans, when this interchangeable mounting method has been worked out in design details, to test the adequacy of the lugs, adapters and other features, both individually and in mounted assemblies. As a preliminary demonstration and inspection, arrangements are being made to have available at the next meeting of the Joint Committee, scheduled for Pittsburgh on May 25 and 26, transformer tanks equipped with lugs, and also crossarm hanging auxiliaries.

Taps

At the Transmission and Distribution Committee meeting in Rochester in February, the question of taps was presented and advantages and disadvantages quite extensively discussed. It was pointed out that the returns from the canvass of advisers showed for the 2400- and 4800-v classes that, in the interest of simplification, dependability and lower cost, approximately four-fifths of kv-a capacity represented favored the omission of taps in the standard transformer.

As to the advisability of taps for transformers of the 7200 to 13,200-v classes, response to Questionnaire Letter No. 3 gave the Committee a good cross-section of views. In the 7200- and 7620-v class, something over 50 per cent of the kv-a requirements reported favored the omission of taps in all sizes (25 kv-a and less). This majority increased to over 60 per cent for sizes of 15 kv-a and less, and to nearly 65 per cent for sizes of 10 kv-a and less.

A substantial majority of the kv-a represented in the 12,000 and 13,200-v class required taps.

The Joint Committee has tentatively decided that the standard transformer will be *without taps,* except in the following ratings.

Voltage Rating	*Kv-a Rating*	*Taps*
7,200—120/240 volts	25 kv-a	3—4½%
7,620—120/240 volts	25 kv-a	4—2½%
12,000—120/240 volts	All sizes	2—5%
13,200—120/240 volts	All sizes	2—5%

Also that transformers *with taps* will be available as special, as follows:

Voltage Rating	*Kv-a Rating*	*Taps*
2,400—120/240 volts	All sizes	4—2½%
4,800—120/240 volts	All sizes	4—2½%
2,400 / 4,800 120/240 volts	All sizes	4—2½% / 2—5%
7,200—120/240 volts	15 kv-a or less	3—4½%
7,620—120/240 volts	15 kv-a or less	4—2½%

It is expected that the next basic problem to be taken up by the Joint Committee will be that of bushings. These will be studied as regards the three present methods of taking leads through the tanks, i.e., cover, side wall, and pocket, also as to coordinating one-bushing and two-bushing requirements. It is anticipated that the results of the preliminary discussion will be circulated promptly to the E.E.I. advisers for constructive criticism. However, the E.E.I. Chairman will appreciate any constructive suggestions in advance of the May 25 meeting.

Electrical characteristics will be taken up promptly upon completion of the review of mechanical features. Electrical features of distribution transformers were given considerable study under the sponsorship of E.E.I. Transmission and Distribution Committee in 1934 and 1935, and it is anticipated that the Joint Committee will be able to make substantial use of the results. Attention is called to papers by Messrs. J. B. Hodtum and W. A. Sumner dealing with Economic Design Factors. These papers, with attendant discussion, may be found as Appendix XI of the minutes of E.E.I. T. and D. Committee meeting held in Buffalo, February 11, 12 and 13, 1935. An abstract was published in *Electrical World* of June 22, 1935, page 32.

Any undertaking to review distribution transformer rated voltages is being deferred to await the findings of the presently active E.E.I.-NEMA Committee on Preferred Voltage Ratings.

The full cooperation of the E.E.I. advisers and those interested engineers who participated in the informal discussion of May 2 is very much appreciated. A few further specific questionnaires to advisers will be needed. E.E.I. members on the Joint Committee, anticipating a continuation of this excellent support, feel confident of success in making available satisfactory transformers at lower prices.

Some Parts That Transmission Lines Play in the Operation of Bulk Power Supply Systems

By Merrill DeMerit
West Penn Power Company, Pittsburgh, Penna.

A paper presented before the Transmission and Distribution Committee, Edison Electric Institute, Chicago, May 3-4, 1939

IN as non-technical a language as possible, I will attempt to give you a physical conception of some of the major bulk power supply operating phenomena which involve transmission lines, and also oil circuit breakers, buses, transformers, and generators. These might be called "power transients of fundamental frequency" and include transient stability, static stability, short circuit currents, and their effect on oil circuit breaker duty, division of load between generators and between transmission lines, and flow and control of wattless current in networks.

The following operating aspects will be excluded from this consideration: Economy of interconnection, contractual limitations and requirements, normal system voltage regulation, bulk power metering, and frequency and time control. These elements were all discussed by Mr. H. S. Fitch at the New York meeting of the Overhead Systems Committee, February 1, 1932, in a paper entitled "Some Phases of the Operation of an Interconnected System."

Time is not available to give a complete exposition of these phenomena. Several books would be required and an appended bibliography contains references if you care to study any one of these subjects.

It may seem that transmission lines play a rather small part in these operating phenomena. However, without transmission lines, interconnections would not be possible and economical location of generation would not be feasible. The lines are necessary links and their continued operation is vital.

Electrical Distances

In all of the subjects to be discussed, ohms, or electrical distance, is more important than geographical distance, and frequently a conception of the electrical distance is helpful in arriving at an economical solution. As an example, the upper diagram in Fig. 1 shows a simple electrical transmission system connecting two generating stations with substations and subtransmission lines, and the lower diagram shows the same system in electrical distances. The generators and transformers are so small that it is impossible to show them to scale geographically, but in the second diagram the major part of the reactance is that of the generators and transformers. The long 132 kv transmission lines which may be a large part of the geographical picture are very short elements in the other.

Generator Characteristics

There are two main generator characteristics which enter into the consideration of many power phenomena. The first is the generator reactance, and the second is the normal kinetic or stored energy in the rotor, which in turn affects its transient stability.

Generator Reactance

Generator reactance is not constant; it varies with large current outputs like short circuit currents, with the time after the short circuit, and with the reactance between the generator and the short.

For ordinary consideration there are three positive phase sequence reactances, the subtransient, the transient, and the synchronous. Subtransient reactance usually runs around 10 to 20 per cent on most large turbo generators—is the actual reactance of the generator winding and is effective during the initial part of a short circuit. As soon as a short circuit occurs on a bulk power supply system the reactance of the generator starts

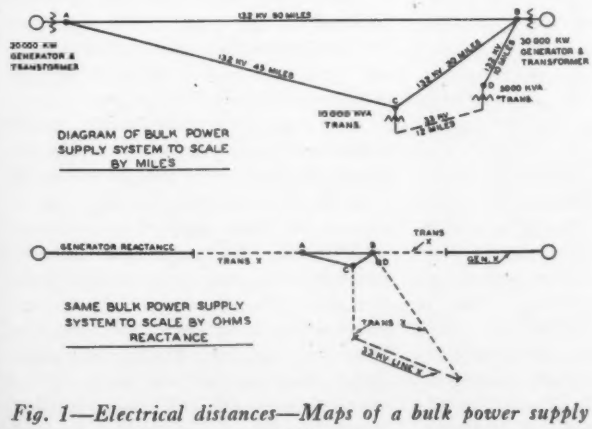

132 KV 90 MILES
30000 KW GENERATOR & TRANSFORMER
132 KV 45 MILES
132 KV 30 MILES
132 KV 15 MILES
30 000 KW GENERATOR & TRANSFORMER
10 000 KVA TRANS.
10 000 KVA TRANS.
33 KV 15 MILES
DIAGRAM OF BULK POWER SUPPLY SYSTEM TO SCALE BY MILES
GENERATOR REACTANCE
TRANS X
TRANS X
GEN. X
SAME BULK POWER SUPPLY SYSTEM TO SCALE BY OHMS REACTANCE
33 KV LINE X

Fig. 1—Electrical distances—Maps of a bulk power supply system

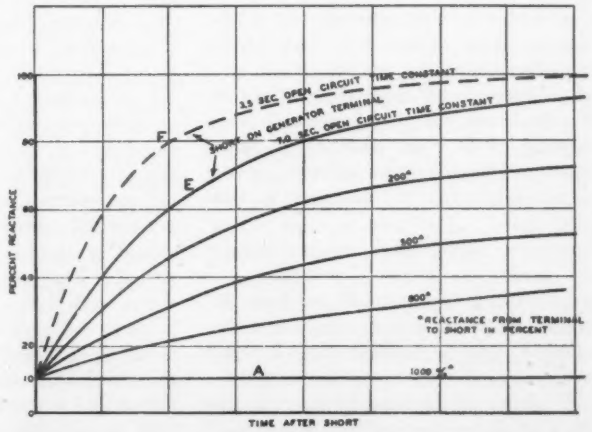


Fig. 2—Reactance of generators under various conditions

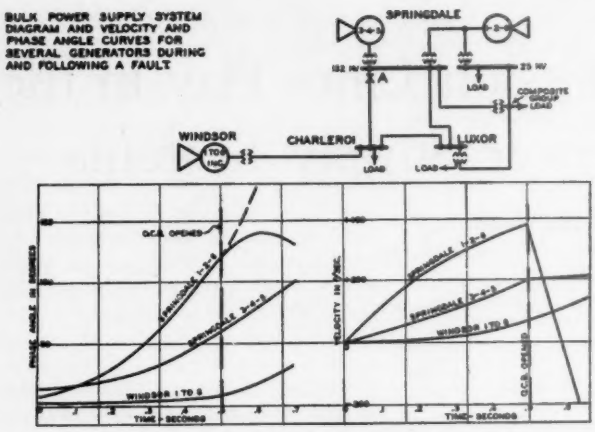


Fig. 3—Transient Stability

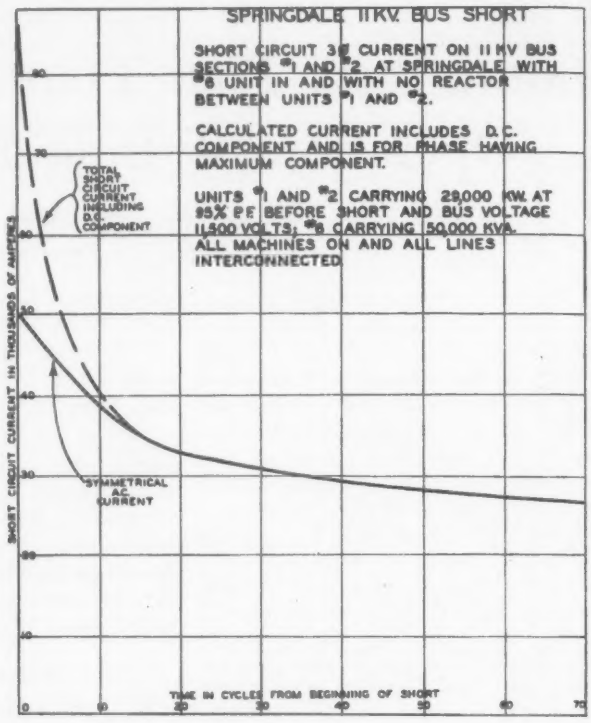

SPRINGDALE 11KV BUS SHORT
SHORT CIRCUIT 3Ø CURRENT ON 11 KV BUS SECTIONS #1 AND #2 AT SPRINGDALE WITH #6 UNIT IN AND WITH NO REACTOR BETWEEN UNITS #1 AND #2.
CALCULATED CURRENT INCLUDES D.C. COMPONENT AND IS FOR PHASE HAVING MAXIMUM COMPONENT.
UNITS #1 AND #2 CARRYING 28,000 KW AT 95% P.F. BEFORE SHORT AND BUS VOLTAGE 11,500 VOLTS; #6 CARRYING 50,000 KVA. ALL MACHINES ON AND ALL LINES INTERCONNECTED
TOTAL SHORT CIRCUIT CURRENT INCLUDING D.C. COMPONENT
SYMMETRICAL A.C. CURRENT
SHORT CIRCUIT CURRENT IN THOUSANDS OF AMPERES
TIME IN CYCLES FROM BEGINNING OF SHORT

Fig. 4

to increase, due to the effect of currents induced in the damper winding or pole tips, etc., and then due to armature reaction it continues to increase. On continued short circuit the reactance will increase and the current will gradually decrease to about full load current, or the equivalent reactance of the generator under these conditions will be about 100 per cent. This is called the "synchronous reactance" and varies from 70 to 150 per cent in large generators.

Fig. 2 shows the reactance of generators under several different conditions, plotted against time after the short. If a short occurs on the system at a point 1000 per cent or more reactance away, the generator will maintain its initial or subtransient reactance, as shown by curve "A" in Fig. 2. Curve "E" shows the reactance of a generator with a short circuit at its terminals. The rates of increase are not the same for different generators, but vary with their time constants. When a generator is operated open circuit with no load and with normal voltage, if the field switch is opened the field flux will continue for a time due to inductance. The open circuit time constant for a specific generator is the time required under those conditions for the terminal voltage to decrease from normal to 36.8 per cent of its initial value. The odd figure of 36.8 per cent is a reciprocal of "e," that is, it is equal to $\frac{1}{2.73}$. Open circuit time constants vary from 2 to 7. In Fig. 2 line "E" shows the increase in reactance of a machine having a 7-second time constant with a short at the terminals, and curve "F" shows the increase in the reactance of a generator having 3.5 second open circuit time constant. These factors are important, both in transient stability and in short circuit current phenomena.

Mechanical Characteristics

Another characteristic which varies widely between generators is the ability to maintain speed for a few cycles when power is shut off. This is determined by the stored energy of the rotor and depends upon its WR^2, or inertia. Most steam generator rotors weigh several tons and revolve at either 30 times or 60 times per second. On a 50,000-kv-a, 1800-rpm generator the rotor is the equivalent in weight of twelve large trucks, bound up tightly, and revolving at a speed of thirty times per second. The surface of the generator rotor travels at a very high speed and so stores a lot of mechanical energy. For instance, a 3600-rpm machine is approximately three feet in diameter and the surface speed is 6.426 miles per minute. You can see that when the rotor is revolving at normal speed considerable power would be required to stop it in a short period. The energy stored in the rotor varies from 2 to 12 kilowatt seconds per kilowatt of generator rating. For an example, a specific 50,000-kw, 1800-rpm condensing unit has a WR^2 of 635,000 pound feet squared, total kinetic energy of 473,200 kilowatt seconds, and an acceleration constant of 22.8°/second²/megawatt. The last figure indicates that for each 1000 kw of unbalanced load applied for a period of one second the rotor will change its speed 22.8 electrical degrees per second. This figure is used in determinations of transient stability.

Transient Stability

Transient stability is the ability of the generators of a system to stay in synchronism when a short occurs on the system, during the short, and following its clearing. Normally all generators are operating with the steam pushing ahead and the electricity pulling back equally. If something occurs to take electrical load off the generator it will accelerate. It takes about 1½ seconds for a steam valve to close, and a lot of things can happen in 1½ seconds.

Now suppose a short occurs on the bulk power system; contrary to prevalent belief, the load of the generator does not increase, it decreases. If the short occurs on the high voltage bus the current will be limited by the reactance of the generator and the transformers which are about 16 per cent and 9 per cent respectively, or 25 per cent total, and these two have about 1¼ per cent copper loss. The current load will be four times normal, the I^2R losses 16 times normal, or 20 per cent of the generator

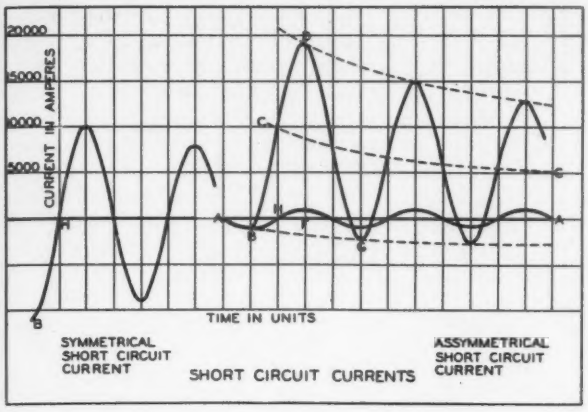


Fig. 5

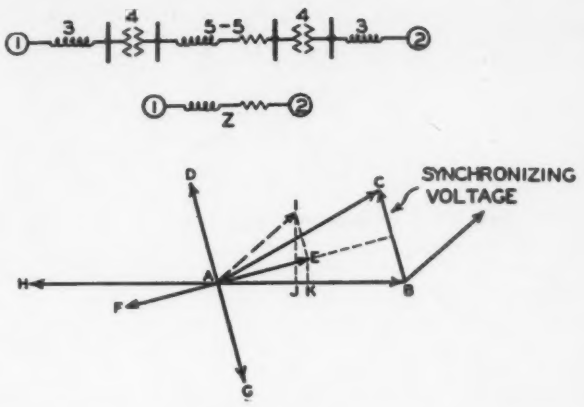


Fig. 6—Line diagram of simple system of two generators and vector diagram showing flow of synchronizing power when generators have different phase angles

capacity, leaving 80 per cent to accelerate the rotor.

Fig. 3 shows the electrical elements of a bulk power system reduced to an equivalent impedance diagram. The main interconnecting links are 132-kv transmission lines each about 30 miles long. The generators are 30,000 to 50,000 kw capacity each, No. 6 at Springdale being a 50,000-kw superimposed unit. Now let us see what happens when a flashover occurs on the 132-kv transmission line at the point "A." As a result of this short circuit generators Nos. 3, 4, and 5 will unload and accelerate. These units have a high WR^2, and so will not accelerate as rapidly as Nos. 1, 2, and 6. No. 6, which is of very light weight, would speed up rapidly, but is connected on the 11 kv bus to units Nos. 1 and 2, which have considerable stored energy. Although the accelerating force on Nos. 1, 2, and 6 is considerably less than it is on units Nos. 3, 4, and 5, nevertheless these three units accelerate more rapidly because of their lower inertia.

The curve at the lower right of the figure shows the angular velocity of the several machines with respect to absolute 60 cycles, and the curve at the left shows the angular displacement of the three groups of machines from that of a generator running at absolutely 60 cycle speed. We will now assume that the switches at Springdale and Charleroi on the faulted line trip and clear the system of this fault in ½ second, or in 30 cycles. The various machines will pick up load instantly and there will be an interchange of synchronizing power between the several groups, tending to bring them together. From the curve in the lower right hand side, units Nos. 1, 2, and 6 at Springdale still have positive velocity, but they immediately begin to decelerate due to the other six machines pulling them back. The electrical brakes on them under these conditions are equal to the brakes on 700 large Buick cars. The current on the 132-kv No. 0000 transmission lines is about 900 amperes per wire. Under the conditions shown the system would maintain stability during the events recited. If, however, the fault had not been cleared until .6 second after the initiation of a fault, the phase angle of units Nos. 1, 2, and 6 would have followed along the dotted line, and when the fault was cleared their angular velocity would have carried them out of synchronism with the other units.

Transient stability depends then upon the number and reactance of the transmission lines, and series units connecting the several generating stations; upon the location of the generators with respect to the fault; upon the stored energy of the rotors, and upon the time required to clear the fault. I wish you would observe that phase angle curves are flat with practically no change until 12 cycles, or .2 seconds after the short. After making a large number of transient stability studies it is difficult to conceive of a system being unstable if the faults are cleared within 8 cycles after the initiation of the fault. This is important in its relation to the capacity of oil circuit breakers because as the elapsed time decreases below 7 cycles, the breaker duty increases rapidly, but the gain in transient stability is insignificant if there is any reasonable line connection remaining.

Short Circuit Currents

Short circuit currents result from line arc overs, etc., and cause mechanical forces, burning of conductors, and heavy duty on oil circuit breakers. The short circuit currents have a high initial value and a rapid decrement, and contain a D.C. component.

The low initial reactance of the generator permits a very high initial current, say 250,000 kv-a per generator initially. In a second the effective reactance of the generator has built up and it will contribute only 136,500 kv-a and later only 40,000 kv-a. Higher initial current and more rapid decrement will exist if the generator is closer to the fault electrically. Of course all of the generators connected to the system will be located electrically at different distances and each will contribute different amounts of current.

Fig. 4 shows a typical curve of a symmetrical 3-phase short circuit current on a power supply system to which approximately twenty-five generators are contributing in various amounts.

An important characteristic of a short circuit current is its D.C. component. This is caused by the inductance in the system, which prevents the current changing instantly. Consequently when a short circuit occurs the current immediately increases, but it must start from its actual value at the time of the short. This is shown by the diagram in Fig. 5.

The small sine curve AA represents the current flowing in a given line at the time a short occurs. The short occurs at the time indicated by B. The current cannot change instantly on account of the reactance of the circuit, but it can instantly assume the rate of change corresponding to the voltage of the circuit divided by the reactance, and it develops about a distorted axis CC as shown. The actual instantaneous values of the currents are the ordinates from the axis AA to the point on the large solid curve and

the current at point D is 20,000 amperes. Consequently there will be a high resistance drop and the effective upper crest voltage will be less than the voltage impressed on the circuit. The tops of the waves are clipped off at each cycle and it gradually assumes its position about the axis A-A. High resistance in the circuit decreases the time required. This current has the same mechanical force and heating effects as a symmetrical alternating current combined with a direct current equal to ordinate AA-CC. The line CC therefore represents a D.C. component, and as drawn is about the maximum that can ever occur. If the short had occurred at the point H on the wave ABH the short circuit current would have been symmetrical.

The cost of oil circuit breakers for transmission line goes up rapidly as the interrupting capacity increases, being about $25,000 for a 132-kv breaker of 2,000,000-kv-a capacity. In Fig. 4 the breaker which would interrupt the current in the first cycle must have a kva rating of approximately double that required to interrupt the current in the 9th cycle. Frequently on an individual system the bulk power supply plant will be equipped with oil circuit breakers of a given capacity, and if the time of opening the breakers is decreased it may result in exceeding the interrupting capacity of the breakers.

As to burning the transmission conductors, tests of 15,000 amperes of short circuit current show that little damage is done in 8 to 10 cycles. Over a period of years there has been a constant urge, and rightly so, to cut down the interrupting time of oil circuit breakers to reduce burning and improve transient instability. However, in most instances when this time has been cut to 7 cycles practically everything has been accomplished and considerable damage may be done or cost incurred by more rapid oil circuit breaker opening.

Short Circuit Stresses on Buses

I am going to say little about short circuit stresses on buses, but will refer you to the General Electric Reports Nos. GEU-50A.2 and GEU-50A.3 which cover this subject rather completely, except for the determination of specific insulator characteristics. Bus stresses build up before an oil circuit breaker can trip and the bus supports must be strong enough to withstand the stresses. On single phase shorts the D.C. component may increase the instantaneous stresses to nearly eight times those computed with the symmetrical RMS and with the standard formula—Force in pounds $= 5.4 \times I^2 \times 10^{-7} \times \frac{L}{S}$ where L is length in feet and S is separation in inches. Also, the vibration period of the busbars by themselves and the period of vibration of the entire bus including the insulators, combine to increase this stress further to 16 or 20 times the computed value referred to. Stress higher than 600 #/ft may occur. This is a subject of considerable magnitude but as related to the bulk power supply oil circuit breakers do not clear the trouble in time to help the bus supports.

Static Stability

Static stability exists when the generators stay in synchronism under normal operating conditions. It is a function of the characteristics of the generators, of the load, and of the reactance and resistance of the links connecting generators, including transformers and transmission lines. The synchronizing holding in power of each generator with the other generators must always exceed any steam load which can be applied to the turbine. If the power factor of the load is reasonably high so that the excitation of the generator is low its holding ability may be low. Static instability may occur in several ways, but only one example will be given. If a superimposed generating unit is operating in parallel with another superimposed generating unit and both are feeding steam to several low pressure generator units, then if one of the high pressure units trips out due to an internal fault, the low pressure units will suck more steam through the remaining high pressure unit and may increase its steam output by 50 to 100 per cent for a while. Under these conditions if the generator does not have enough synchronizing power to hold it in synchronism it will be pushed ahead out of synchronism by this excess steam. This ability to hold in depends upon the characteristics of the generator and its internal voltage and its system connections.

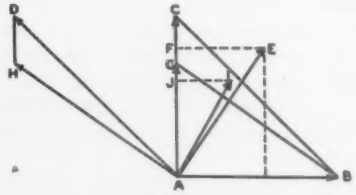


Fig. 7—Vector drawing of two generators operating in parallel showing decrease in synchronizing power with decrease in air gap voltage

Fig. No. 6 shows a diagram of two generators interconnected by transformers and transmission lines. The transmission lines and other impedance links have all been combined to give one equivalent connection between the two generators. One and two are the two generators, three is the generator internal reactance, four the transformers, and five the transmission lines. If charging currents are neglected an entire system can be reduced to one electrical equivalent, as in the simple diagram below the first, which shows the two generators and an impedance Z. If excess steam is applied to unit No. 1 it must be held in synchronism with the other by its synchronizing power. In the vector diagram, AB represents the air gap voltage of unit No. 2. Steam is applied to unit No. 1 and tends to make it advance relative to the other, and as it advances mechanically its voltage advances in phase and is represented by vector AC. The two terminal voltages will be different by the amount CB and will tend to make current flow between the two generators. This difference in voltage which is impressed on the circuit of impedance Z is equal to AD, and if we assume that the circuit is all reactance the current which flows will be AE lagging 90° behind AD with reference to machine No. 1. Of course it will go in the opposite direction in machine No. 2 and can be represented by AF. The current is almost in phase with the voltage AC and is power current with respect to generator No. 1. This generator will generate power equal to AE x No. 2 will act as a motor taking power equal to AF x AB x the cos of the included angle. This will tend to make generator No. 2 speed up and the two units keep in step. If there is a larger proportion of resistance in the system connecting two generators the current may be AI and the synchronizing power will be less.

Fig. 7 is very similar to Fig. 6 except it shows the air gap voltages of generators Nos. 1 and 2, 90° out of phase, and shows two different air gap voltages for generator No. 1, that is, AC in the first instance and AG in the second. The synchronizing voltages would be respectively AD and AH and the synchronizing current AE and AI respectively. The synchronizing power tending to hold back the generator would be AC x AF in the first case, and AG x AJ in the second case. It is evident that with the decrease in internal voltage both the effective synchronizing current and the

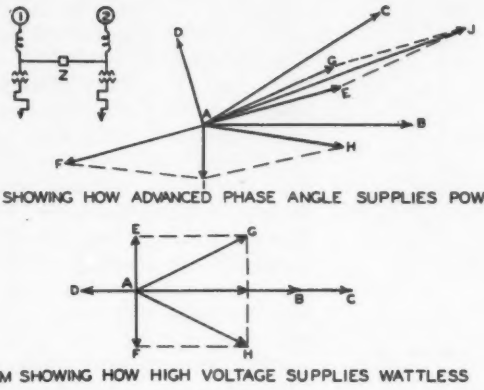


Fig. 8

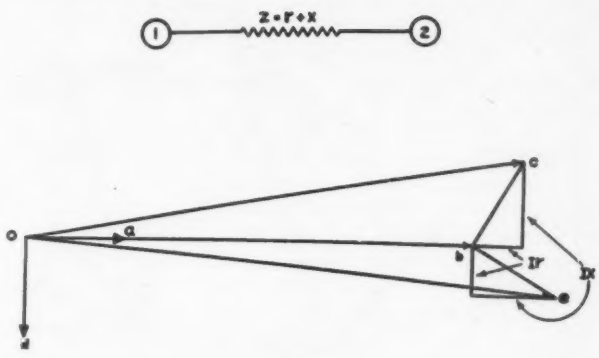


Fig. 9

synchronizing voltage decrease, or the synchronizing power goes down about as the square of the voltage.

This diagram also shows that as the leading generator tends to slip out of synchronism the current on it becomes lagging, which gives it a high field demagnetizing effect and tends to decrease the internal voltage. For this and other similar reasons it is advisable to reduce the relative demagnetizing effect of wattless current, and this is done in a large generator by making the air gap large. This increases its short circuit ratio and improves its static stability characteristics. Most large generators have air gaps of around 1½ in. to 2 in.

Superposition of Currents

Quite frequently in the solution of power system problems it is convenient and simple to use superposed currents. I think Maxwell first found that if two voltages are applied to a circuit at the same time the resulting current is the same as the sum of the currents caused by the two acting independently. For instance, to determine the effect of a booster or phase advancer on a closed network we can first determine the flow of all currents without the booster installed. We can then consider all other sources of voltage removed and the booster acting as the source of voltage on the line on which it is to be used. The resulting currents in the several lines can then be added to the previously existing currents to determine the total current in each line. The superposition of currents is used in the following considerations:

Flow of Power and Wattless Current Between Generating Stations

When two similar direct current generators operate in parallel the machine that has the highest voltage takes the most load. With alternating current generators this is not true. The generator or generating station which has the advanced *phase angle* generates the load regardless of voltage, and the generator which has the highest voltage generates the *wattless current*.

In the line diagram in Fig. 8 the two generators or generating stations are in parallel and connected to loads. The two generators have identical characteristics and voltages, and consequently the load currents will divide equally between them and are shown as AG and AH respectively. If we advance the phase angle of unit No. 1 and determine the resulting current that will flow between the generators and then superpose these currents on the load currents, we will have the total currents on each generator. This diagram is very similar to that shown in Fig. 6 and the action is similar to that described. The machine No. 1 with the advanced phase angle supplies current AE to machine No. 2, which is run by machine No. 1 as a motor. If the load currents are then superposed, the current on generator No. 2 will be AF plus AH, or zero power, and the current of generator No. 1 will be AG plus AE, or AJ. That is, generator No. 1 will take all the load and generator No. 2 will carry nothing. In other words, the generating station with the advanced phase angle carries the load.

Now to consider the effect of high voltage; the second part of the diagram shows the voltages for generator No. 1 and generator No. 2 in phase, but the voltage on No. 2 is now higher, being AC, and that on No. 1 equal to AB. The voltage on No. 2 exceeds the voltage on No. 1 by the amount BC, and this will cause current to flow through Z equal to $\frac{BC}{Z}$, and since the circuit is all reactance, it will be lagging current and have phase relation AF. This will flow through generator No. 1 in the opposite direction, of course, and will have the phase relation AE with reference to generator No. 1. If the load currents are now superposed on the other currents the resulting currents will be AG on No. 1 and AH on No. 2. That is, the generating station with the higher voltage will carry the wattless. Of course the phase angle is advanced by opening the steam valves and the voltage is increased by raising the excitation.

So in the bulk power system power flows from the advanced phase angle and wattless flows from the high voltage. This is true on the transmission network and the individual lines interconnecting generating stations, because each is a link in a circuit connecting two generating stations. A synchronous condenser on the end of a transmission line is a generator with a retarded phase angle and high voltage. In that case power is flowing to the synchronous condenser and wattless current is generated by the synchronous condenser and flows back towards the power house.

Flow of Power and Wattless Current in a Network

From the transmission and distribution standpoint the previous case is a special one in which the interconnecting link between generators is practically all reactance and with no resistance. Actually the ratio of $\frac{x}{r}$ is usually about seven in links between generating stations.

If there is an appreciable amount of resistance in the circuit or network then both advanced phase angle and increased voltage are required to make power flow from a point. A retarded phase angle and high voltage are necessary to make wattless flow from the same point.

This is shown in Fig. 9 in which the two points No. 1 and 2 may be the ends of two transmission lines, or two

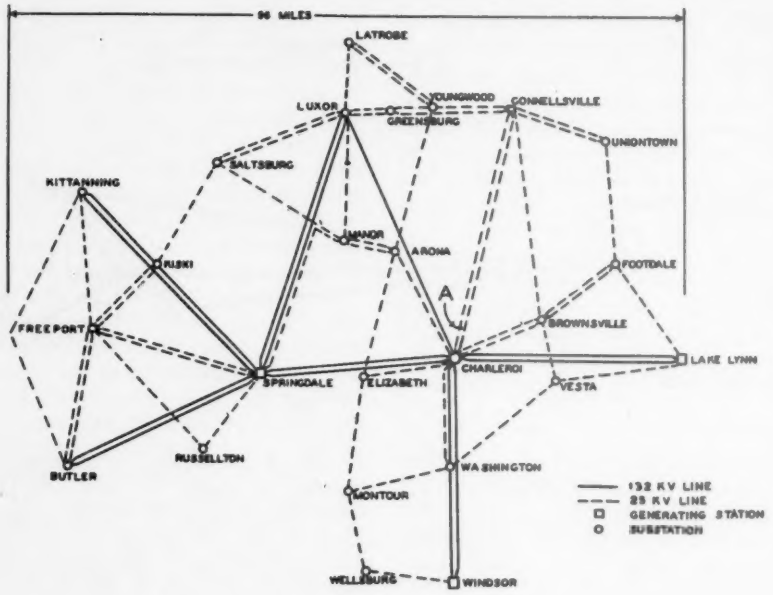


Fig. 10

generators and the impedance connecting these two points has a resistance of r and a reactance of x. If the voltage at point No. 1 is ob and the voltage at point No. 2 is oc, then current oa will flow between the two points and the voltage drop will be bc, or the vectorial sum of Ir and Ix. If the voltage at 2 happens to be oe, then current od will flow and the voltage drop will be be, which again will be made up of Ir and Ix. Conversely, if you want a certain current to flow between two points you must introduce a voltage in the circuit which is equal in magnitude and direction to the voltage drop which will be caused by that current in the circuit in which it will flow.

Voltage Drop and Phase Angle Change in Transmission Network Operation

There is no need to elaborate to this group on the advantages of operating a closed network. It results in the greatest economy of transmission, provides the largest number of feeds to the several points with the minimum number of lines, obtains the best voltage regulation with the minimum copper, but on the other hand it causes a great many headaches in the determination of the voltage drop, the flow of current and the loads that will be carried by the several lines.

We operate a large transmission network covering about 8000 square miles, made up of 425 units and consisting of generators, transformers, reactors, about 550 miles of 132-kv lines and 1400 miles of 25-kv line. In all cases the 132-kv lines connect in to the network at both ends, but the 25-kv lines are generally connected in at three points. A portion of this system is shown in Fig. 10. Many of the 25-kv lines are left out, but enough are included to show the method of connection. With a system like this when power generation is transferred from one generating station to another or load is added at any location, the current is changed in all of the lines. For instance, if we increase the generation at Connellsville by 30,000 kw the effect is to make 1000 kw change in the flow from Freeport toward Springdale on the Russellton line. The current flowing to Butler on the 132-kv line is increased, and similarly it is changed in all the rest of the links.

In this system the voltage was low in the network at Connellsville. Also the 132- to 25-kv transformers at Luxor were carrying more than full capacity, while the 132- to 25-kv transformers at Charleroi were not fully loaded.

If Connellsville had been fed by a radial line a voltage booster could have been put in that line and boosted the voltage at Connellsville by a definite amount. However, since Connellsville is connected in a network, if a booster is installed in a line at the point "A" it causes wattless and power current to flow from Charleroi to Connellsville, and the current returns over the several other routes from Connellsville back to the point of beginning. The currents in the several lines would be of various power factors and amounts, the vectorial sum of which will be equal to the boosting voltage divided by the total impedance of the loop about which current is circulated.

To determine this impedance it is necessary to draw up a diagram of the impedance links between "A" high side and "A" low side of the booster, as shown in Fig. 11, in which each link represents a transformer or a transmission line. The impedances are 25 kv base and by network analysis can be reduced to a single impedance, and the total current flowing from "A" to Connellsville for any voltage boost or phase advance can be determined. This network can readily be solved by two or three men working three or four weeks. The impedance of the loop is 14.36 + j17.93 ohms, so that if a 10 per cent boost, or 2500 volts is put in the line at "A" it will cause 68—j85 amperes to flow in the loop "A-A."

Fig. 12 shows this relationship for one phase. We will assume that the boost is taken off the transformer represented

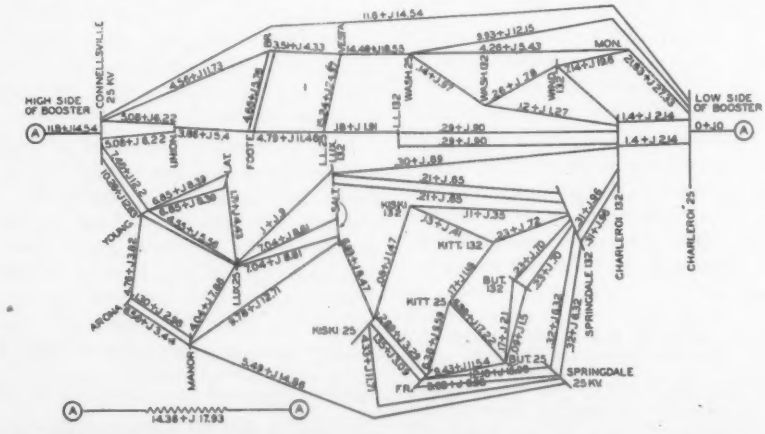


Fig. 11—Diagram showing impedance through which booster circulates current

by the phase "B" and is equal to "AB." It will then cause the current OB^1 to flow in the loop. This is 68—j85 amperes referred to "AB," but it is 96 + j52 amperes referred to the line voltage "OB." If the phase "C" is used for the booster, the boosting voltage will be "AC" and the circulating current OC^1, etc. It is necessary to choose the booster which will accomplish the purpose in mind. There is no definite method of taking care of such things—you first have to guess what can be done and then analyze the effects to see whether the purpose will be accomplished. This is something like milking a cow, you can't learn much about it by reading a book, but after you do it a while it seems easy.

Referring again to Fig. 11, the current which flow in each link due to the booster can be determined by reversing the simplifying process and breaking down the single impedance into the several impedances shown, and calculating the currents step by step. The current in each line and transformer can then be superposed on the currents which flowed in the network originally and the new voltage drops and rises calculated link by link, and the changed load on the substation transformers determined.

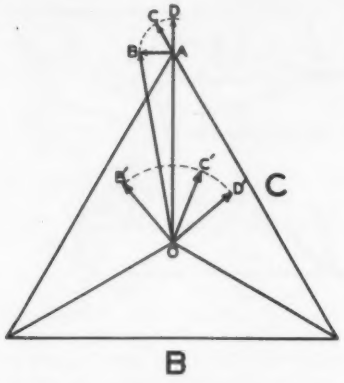


Fig. 12—Vector diagram of voltages on a 31 transmission line with various natural voltage boosts and phase advances added also currents which these boosts would force through a loop of impedance. Z = 14.36 + J 17.93 at 25 kv. base

The simplest and most economical form of phase advancer or booster consists of a transformer bank connected across the line with the secondaries connected in series with the wires, and it can be either fixed or variable. A fixed booster at 25 kv of the kind described will cost about $10,000, and a variable booster will cost about $25,000.

Fig. 13 shows a portion of a network with one step in its simplification. One line is eliminated by means of a delta calculation, and in a similar manner by delta, parallel, or star calculations the other lines can be combined and the network reduced to a single impedance.

In the problem used as an example and relative to the diagram shown in Fig. 11, we combined the whole into an equivalent impedance solved for the current and its phase relation and voltage drop and then segregated them into their component parts, and determined the values for each impedance element or line as it was broken down.

Now there are three ways to do this kind of a job. One is by rigorous calculations as indicated previously; the second is by the use of a Calculating Board; and the third is by cut and try. The

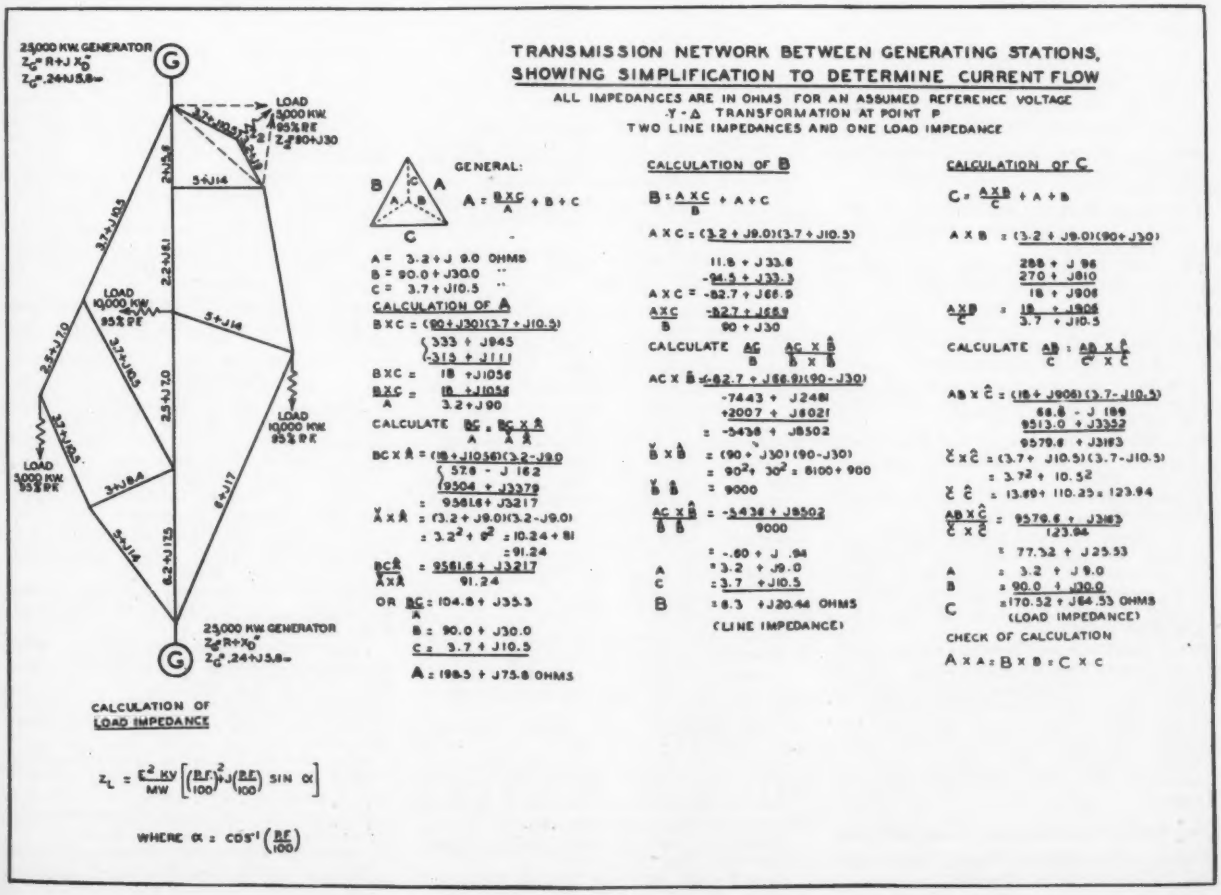

TRANSMISSION NETWORK BETWEEN GENERATING STATIONS, SHOWING SIMPLIFICATION TO DETERMINE CURRENT FLOW
ALL IMPEDANCES ARE IN OHMS FOR AN ASSUMED REFERENCE VOLTAGE
Y - Δ TRANSFORMATION AT POINT P
TWO LINE IMPEDANCES AND ONE LOAD IMPEDANCE
25,000 KW. GENERATOR
LOAD 3,000 KW. 95% PF
LOAD 10,000 KW. 95% PF
LOAD 10,000 KW. 95% PF
LOAD 3,000 KW. 95% PF
25,000 KW. GENERATOR
GENERAL:
CALCULATION OF A
CALCULATION OF B
CALCULATION OF C
CALCULATE AC/B
CALCULATE AB/C
CHECK OF CALCULATION
CALCULATION OF LOAD IMPEDANCE
WHERE α = COS⁻¹(PF/100)

Fig. 13

Calculating Board is a large number of variable resistances and reactors units combined with miniature generators of adjustable phase angle and voltage with which a miniature of the system can be built, loads applied and values measured. The cut and try system consists of assuming certain values in certain places and making checks.

On a large problem similar to that indicated the work can be done by rigorous solution in about 40-man days. The same thing can be done by two men on the Calculating Board in about two hours. A reasonable solution can be made by cut and try in three or four days if the man who is doing it is good enough on guessing his "try" values. We have used all three methods.

In the cut and try method we set the known values on the diagram, assume certain flow of power and wattless current and then make trials of different loops, adjusting the values until we get reasonable reconciliation of the following three things: First, IZ moments between any two points over any two routes must be practically the same. This is shown in Fig. 14. We may have the voltage AB at point B, and AC at C another point on the network. Then the voltage drop is always BC between the two points regardless of what route is chosen. For instance, over one route a current AD will have a resistance drop of BD_1 and reactance drop of D_1C. Or, over another route the current AF may have a resistance drop of BF_1 and a reactance drop of F_1H, to an intermediate point, but from that point to C the current AG may have a resistance drop of HG_1 and a reactance drop of G_1C. Although a disproportionally large phase angle is used for clarity, it is evident that the IZ moments will be practically the same over any route. The second condition is: The sums of components of power and wattless current into any point must be zero. The third is that the actual voltage drop by all routes between the same points must be the same.

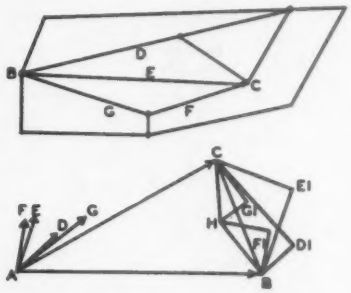


Fig. 14—Diagram of network in which voltages AB and AC exist at points B and C. Vector diagram shows that ΣIZ between points B and C are practically the same by any route

Calculations are simplified if the trial currents are checked in the three ways in the order given.

Conclusion

I have tried to give you my physical conception of a few system phenomena which occur in the operation of transmission lines, but do not pretend that this is a complete exposition of any one. That can be obtained by studying the writings referred to in the appended bibliography.

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(*Continued on page 271*)

Combined Overhead and Underground Network of the Detroit Edison Company

By Harold Cole
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A paper presented before the Transmission and Distribution Committee, Edison Electric Institute, Chicago, May 3-4, 1939

BEFORE describing the system of distribution which is being used to supply alternating-current service in the former direct-current district of Detroit, I think a little historical background will be helpful to a better understanding of the reasons for the adoption of the particular system.

The early development of the Edison system in Detroit extended into a considerable area of the city which was at the time almost entirely residential. The downtown section was served first, of course, and this portion of the system was largely placed underground but, as expansion was made to serve the residential districts where load densities were low, the cost of underground construction was practically prohibitive and was used only for the outgoing feeders from the generating stations, the mains and services being almost entirely overhead. The fact that a rather complete system of alleys was provided for the use of utilities in the Detroit plan of street development made the use of overhead lines much less objectionable than would have been the case if all the lines had been required to be located in the streets. In the course of time, as loads increased and business districts expanded along the main thoroughfares, much of the network of direct-current mains were reinforced by underground ties, and where the overhead lines were located in important streets or in alleys in congested districts, they were entirely removed, but in a considerable part of the d-c district the overhead mains and services were still retained in the alleys to serve the older buildings and residences.

The advent of the more economical a-c system of high voltage distribution stopped the expansion of the d-c area about the turn of the century and after that all extensions of electric service into new territory were taken on the a-c system. The d-c system had by this time covered an area of about 3¾ square miles and no appreciable changes were made in its boundaries for about two decades. During this period, direct current was considered the preferred service due to the greater reliability and the better suitability of motors for certain applications, notably for the operation of elevators in large buildings.

The heavy growth in the load on the d-c system was fortunately confined to the downtown district and the area in the vicinity of the main radial highways out of the downtown district. A large portion of the east side of the d-c district deteriorated to a slum district. A study made in 1924 indicated that the complete cutover of this slum area could be well justified, even though we undertook to replace all motors and appliances which were not suitable for a-c operation. The amount of equipment requiring change was small in this particular area, the salvaged material could be utilized in other parts of the system, and, if the cutover had not been made, large expenditures would have been necessary on the d-c system to handle industrial loads which were starting to develop in the area. The cost of the standard radial overhead a-c system, which was entirely satisfactory for use in 98 per cent of that area, was, of course, very much less than that of the d-c system it replaced.

The cutover of about one-third of the d-c area was made in 1925, 1926 and 1927. This reduced the remaining area to practically the downtown district and a strip five or six blocks wide extending north about two miles on either side of Woodward Avenue, plus some territory on either side of the downtown area of mixed commercial and industrial character. See Fig. 1.

In this remaining area it was not thought feasible to use a radial system of distribution. Pole lines had been generally removed from the streets, so that, while it was possible to install overhead transformers in the alleys in a large part of the area outside of the "loop" district, the main feeders and primary ties between alleys had to be placed underground. A radial system was not considered sufficiently reliable under these conditions. The use of an a-c underground network, which was in the early stages of development about this time, was a possibility but the cost of a system of underground vaults and submersible transformers made this system considerably more expensive than the radial overhead system. Furthermore, the experience in cutting over the east side area had demonstrated that the cost of changing customers' equipment in a commercial district or in a high-class residential district was very great, and therefore the immediate forced retirement of the d-c system could not be justified in the remaining d-c area.

The matter of further d-c cutover, therefore, rested for several years, but the necessity for new substations and feeders and the constant reinforcing of d-c mains to take care of load increases made it evident that some solution to the problem should be worked out.

The situation would have been much worse, however, if the growth of the d-c load in the downtown area had not been held down very materially by the policy adopted about 1922 of serving all customers having a demand of over 200 kva with alternating current at 4600 volts by means of a loop line scheme. By 1929 nearly 40 per cent of the load in the so-called d-c district was being carried on the a-c system and d-c load growth in the downtown area had practically stopped.

About the time the depression set in, there had developed a real demand on the part of customers in the d-c district for a-c service due to new developments in a-c appliances, especially a-c radios, and due to the cost of changing over equipment when moving from one district to the other. It then became fairly certain that if a-c service were made available to the customers in the d-c district, a great many would be glad to make the necessary changes in their equipment at their own expense in order

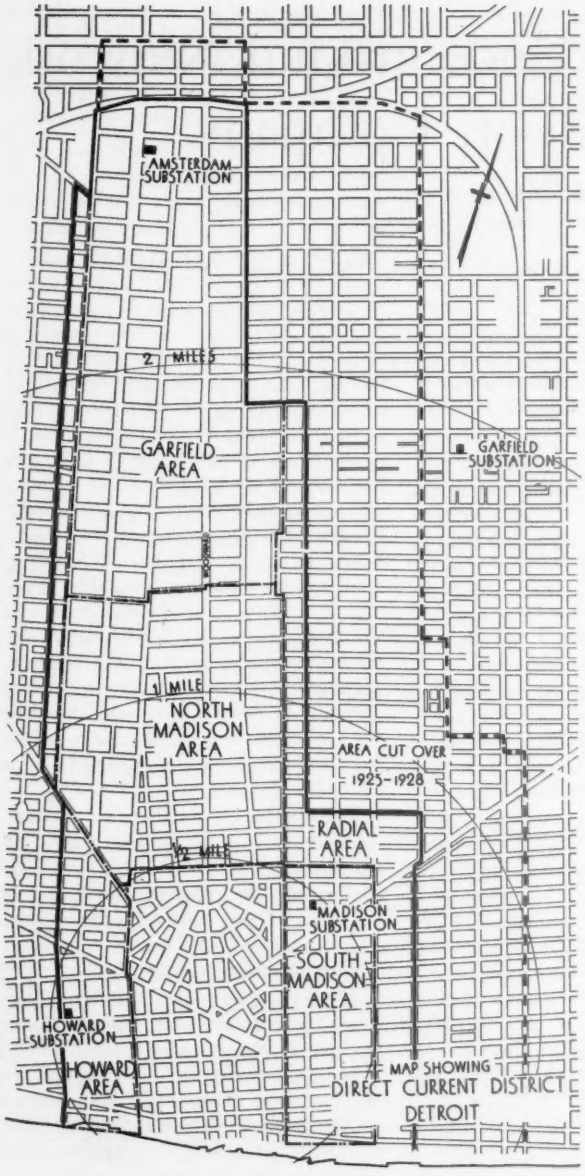


Fig. 1—Map Showing Direct Current District

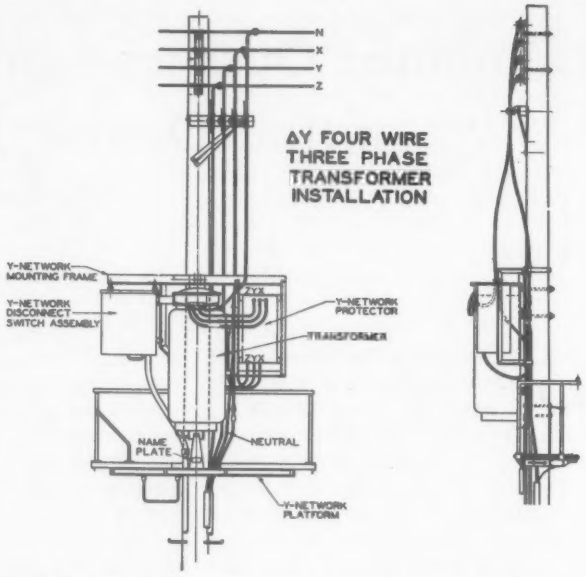


Fig. 2—Overhead Network Transformer Installation

to get the now preferred a-c service. If an a-c network scheme could be worked out which could be installed without too great an initial investment and the increment cost for making extensions could be kept low, it looked like a good time to prepare to take practically all new loads on the a-c system and to get as many customers as possible cut over from the d-c system so as to permit those remaining on direct current to increase their loads without requiring any appreciable added investment in the d-c system.

After a study of the various possibilities of providing a highly reliable a-c distribution system which would show the lowest overall cost under the prevailing conditions, a modified form of a-c network which will be described in this paper was evolved. The main features of the scheme are:

1. The primary supply consists of two 4,800-volt feeders, both from the same substation, to which are connected all of the transformers in a "network area." The feeders are three-conductor lead sheath cable from the substation to the network transformers. No open wire primaries are used.

2. The transformers and secondary network protectors are mounted on poles located in alleys. The transformers are three phase for 120/208-volt four-wire secondary.

3. The secondary mains are either overhead or underground, or both, depending on the character of the district and of the load to be served. Two transformers, one connected to each of the two primary feeders, are connected to the same secondary main to provide network service in one or two blocks in the initial stages of development. No attempt is made to build up a large secondary grid until there is some advantage to be gained in improving voltage regulation, or load division, or in producing a sufficient amount of short-circuit current to an underground cable fault.

Transformer Installations

A method of mounting the transformer and its accessories was worked out to facilitate installation, inspection and maintenance. (See Fig. 2.) The transformer, the network protector box, and the box housing the primary disconnects are mounted on a steel frame in such a way that they are readily accessible from a sturdy steel and wood platform of rather unique design. The primary cable is brought in to the bottom of the steel box housing the primary disconnects and simple fan-out is used to terminate it. The primary disconnects are stick operated knife-switches mounted in porcelain cutout boxes. The connection from the disconnects to the transformer utilizes a short piece of paper and lead cable with a fan-out on either end which runs through a flanged pipe connection between the disconnect box and the transformer case. The secondary network switch with its relays is mounted in a weatherproof box, and open wire is used to connect it to the transformer and to the overhead and underground secondary mains. Secondary fuses are of the so-called copper-link type mounted on a bakelite base and are inserted in the leads on the secondary line side of the protector.

The transformers, which are of the

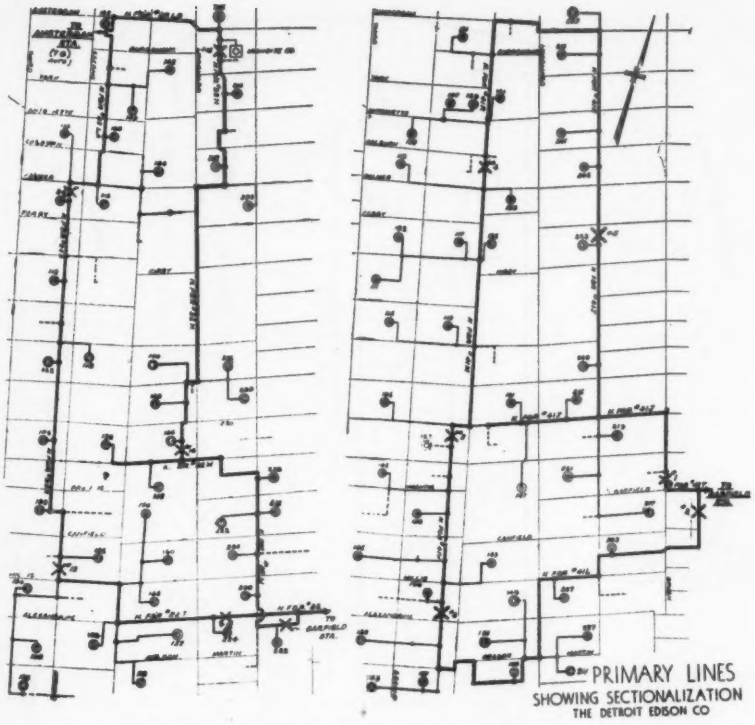


Fig. 3—Primary Lines Showing Sectionalization

so-called "stacker" type, actually consist of three standard single-phase core and coil assemblies mounted one above the other in one case. If, in the future, due to load increases or other developments a surplus of any size accumulates, the individual single-phase units may be installed in single-phase transformer cases for use elsewhere at very little cost.

Primary Design

It was thought inadvisable to employ sensitive operation of the network protectors on this system for reasons which I will not try to discuss at this time. It is, therefore, necessary to have an operator disconnect by hand all of the transformers connected to a primary cable in order to do any work on the cable. To reduce the time necessary to perform this operation and also to minimize the probability of service outages in case of the failure of one feeder while the other feeder is intentionally out of service, it was decided to sectionalize the primary feeders by means of hand-operated air-break switches. Fig. 3 shows on separate maps the two feeders of the Garfield Area showing the sectionalizing switch locations. A maximum of about ten transformers are connected to any one section of the feeder and as the sectionalizing switches may be opened under load, it is unnecessary to open the station breaker to make a shutdown of a section. In general, ring-mains or loops are used to make it possible to maintain service to all sections except the one on which work is to be done. The sectionalizing switches are mounted in steel cubicles above ground at the side of a convenient alley. The cable is brought into the base of the cubicle and is fanned out and each phase connected to one pole of the air-break switch which is of a type designed by our own engineers for this kind of service.

In order to provide against an outage of the network due to a shutdown of the substation from which the network is normally supplied, a tap to one of the two feeders is carried to a second substation and automatic throw-over is provided to pick it up from that substation. Fig. 4 shows the primary layout of the Garfield Area and Fig. 5 shows the secondary layout for the same area.

Secondary Design

The underground secondary cables used in the early construction were three-conductor, 4/0 paper and lead which had been rejected for 4800-volt service. About 40 per cent of the secondary cable now in service is of this category. Recently installed secondary cables are mostly single-conductor, 4/0 rubber and lead, but a considerable amount of single-conductor, 4/0 paper and lead was installed at one time and a small amount of Rockbestos cable was used.

Considerable care was taken in making extensions to the system which involved underground secondary cable to see that the short-circuit current to any point in the cable under fault conditions did not fall below about 5000 amperes which had been indicated by tests to be very likely to burn clear any secondary fault. Whether this will be proved true in service or not remains to be seen as we have no knowledge of any secondary faults having developed.

Overhead secondary mains are usually of No. 0 or larger weatherproof copper cable carried on secondary racks.

Method of Development

The area in which the so-called overhead network service has now been made available, which is known as the "transition area," covers all of the former d-c district except the strictly downtown area where pole lines in alleys are prohibited, and some small fringe areas where radial a-c service was considered sufficiently reliable. There are four separate networks and the total area covered is about 1.75 square miles. The procedure followed in the development of the areas was to install the feeder from the substation to the area and a main skeleton of the primary mains throughout the area so that only short primary extensions plus transformers and secondary mains were necessary to make service available in any part of the area. In general, the final service extensions were not made until a service inquiry was received from one or more customers whose load was large enough to justify the added investment, although consideration was always given to the character of adjacent customers to whom a-c service would be made available. In some of the better residential areas a complete secondary network was installed immediately, as the cost of the extension to any one customer could not be justified, but it was certain that a large percentage of them would gradually make the change if the service was made available. No solicitation was made at any time to induce customers to change over. New buildings or new tenants in old buildings were nearly always taken on the a-c system, thus preventing the addition of much d-c equipment to the d-c system which would later be costly to change to a-c operation. Only the elevators were permitted to remain on the

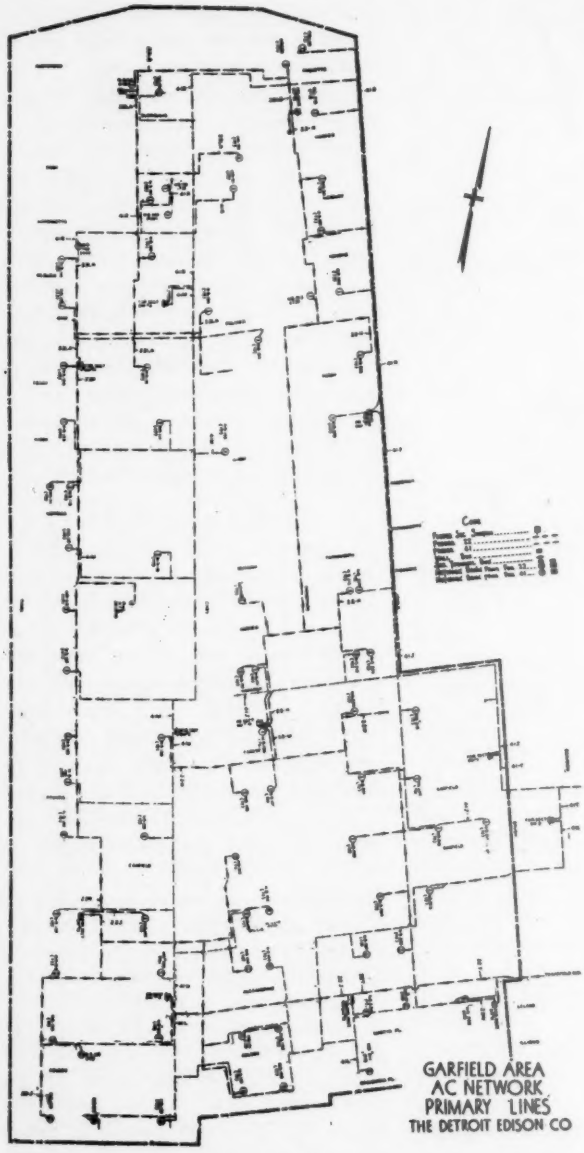


Fig. 5—Garfield Area—A-C Network Primary Lines

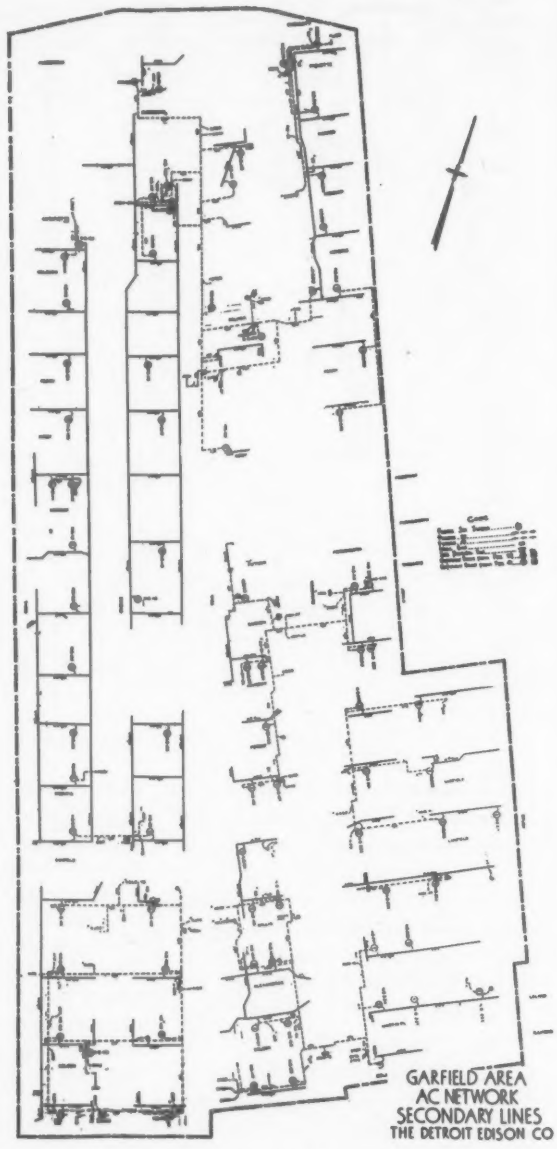


Fig. 4—Garfield Area—A-C Network Secondary Lines

d-c system in old buildings which were changed over.

Progress of Changeover

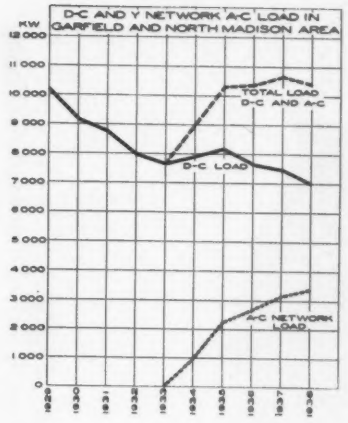
It is interesting to note the differences in the rate of changeover in the different portions of the transition area. Fig. 6 shows the location of all of the network transformers in the transition area and gives some indication of the amount of changeover.

In the northernmost network area, known as the Garfield Area, which is largely residential but which is in the process of change to an apartment and rooming house district, nearly one-half of the load has been transferred to the a-c system. In the North Madison Area, which is between the Garfield Area and the "loop" district there has been much less cutover and the present a-c load in this area is only about one-sixth the d-c load. There are many second-rate hotels, cheap rooming houses and blocks of small stores and offices in this area which have been difficult to induce to change under our past policy of giving only one kind of service to any one building. Consideration is being given to modifying this requirement so that individual tenants in a building may be changed over separately. In the two network areas east and west of the downtown district (South Madison and Howard Areas) the change has been still slower and very little has been picked up but the new buildings of less than 200-kva demand. The ability of the network to pick up these loads at a low increment cost and to keep them off of the d-c network justifies the investment, however, as the addition of large d-c load in these fringe areas usually involves a considerable bolstering of the d-c network and the later expense of changing over the customer's equipment is avoided.

Low Initial Cost

The actual construction work on the new network was begun in 1933. The cash expenditures were surprisingly low to get the system started. A large part of the ducts necessary for the underground cables were available in conduits

At Left: Fig. 6—Map Showing Network Transformers in D-C District



At Right: Fig. 7—Load in Garfield and North Madison Areas Showing D-C and A-C Network Loads

already installed to carry the feeder and main cables of the d-c system. Most of the necessary primary cable was either in stock with no prospect of being used for several years or was available by pulling out cables no longer required for service to large customers where load requirements had fallen off due to the depression. A considerable amount of cable was also on hand which was so old that it had been rejected for use as primary cable but was satisfactory for secondary cable. About the only cash requirement, aside from the transformers and network protectors which were installed only as required, was for the small additional conduit required and for the labor of installing the cable. Even the labor cost was hardly a cash requirement as construction forces had been reduced to the minimum necessary for emergency needs and there was still not enough work to keep them busy.

Present and Future Costs

The cost of the a-c network per kva of load will obviously vary considerably in the different network areas, due to the variation in the load densities in the districts served by the different networks. An analysis of the cost of the network in the Garfield Area, however, will give us a fair idea of the ultimate cost of the system. Table I shows the approximate costs of the a-c network in the Garfield Area as it is at present, and also an estimate of the cost of a network for double the present load.

The costs given in Table I do not include any charge for the conduits already installed in the area for the d-c cables and for other a-c cables. There are about 120,000 feet of duct occupied by the present system, and it is probable that the cost of new conduit to carry these cables with spare ducts for future

TABLE I—APPROXIMATE COST OF A-C NETWORK IN THE GARFIELD AREA

Present Condition	*Double Present Load*
Transformer Capacity	Transformer Capacity
19-45 Kva = 855 Kva	25- 45 Kva = 1,125 Kva
64-75 Kva = 4,800 Kva	80- 75 Kva = 6,000 Kva
	20-150 Kva = 3,000 Kva
Total Capacity...5,655 Kva	Total Capacity ..10,125 Kva
Present Load.....2,500 Kva	Assumed Load ... 5,000 Kva

Estimated Investment	*Present Condition*	*Double Present Load*
Conduit required to be added	$ 80,000	$120,000
Primary Cable	120,000	190,000
Sectionalizing Switches	15,000	20,000
Transformer Installations (excluding transformers)	75,000	110,000
Transformers	50,000	85,000
Secondary Cable	40,000	70,000
Overhead Secondary Conductors	30,000	30,000
	$410,000	$625,000
Cost per Kva Load	$164	$125
Cost per Kva Transformer Capacity	$ 73	$ 62

Fig. 8—Side View of Typical 75 Kva Overhead Network Transformer Installation

Fig. 9—Front View of Typical 75 Kva Overhead Network Transformer Installation

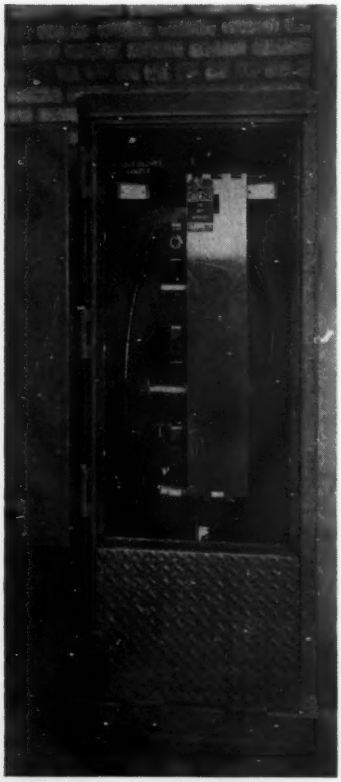


Fig. 10—Primary Sectionalizing Switch

growth might add $200,000 to $300,000, or even more, to the cost, depending upon how much care was taken to provide segregation of primary cables to prevent simultaneous outage of both network feeders. Also, no substation costs are included.

Advantages

The important advantage of the use of overhead transformers is that it reduces the initial investment necessary to give service without increasing the ultimate cost. The cost of a 75-kva transformer installation with its network protector, platform, etc., is about $1,500, and network service can be carried to a new customer for a maximum of about $5,000 after the skeleton primary system has been installed. This is probably less than half of the cost of a minimum underground installation and a large part of this expense may be recovered if, for any reason, service is discontinued or if, later on, larger underground transformer installations are required. An-

(*Continued on page 272*)

TABLE II—SYSTEM DATA

Number of Network Areas	4
Total Area of Network Areas	1.75 square miles
Total Network Load (non-simultaneous)	4,300 Kva

Transformers

144-	75 Kva =	10,800 Kva
26-	45 Kva =	1,170 Kva
2-	150 Kva =	300 Kva
172		12,270 Kva

Primary Cable

32,000 feet, 3-conductor, 450M-cir mil in feeders
127,000 feet, 3-conductor, #4/0 in mains
64,000 feet, 3-conductor, #2 in taps to transformers

Secondary Cable

150 circuit feet 500M-cir mil for 150-Kva pole ends
13,000 circuit feet 350M-cir mil for 75-Kva pole ends and mains
65,000 circuit feet #4/0 for mains

Network Protectors

200 ampere for 45 and 75-Kva transformers
400 ampere for 150-Kva transformers

Network Voltage Studies

By M. W. Ghen
Duquesne Light Co., Pittsburgh, Penna.

A paper presented before the Meeting of Subject Committee on Underground Methods and Accessories, Transmission and Distribution Committee, E.E.I., Rochester, N. Y., Feb. 8, 1939

IN the operation of large, low-voltage A-C networks, it is sometimes necessary to secure a general picture of voltage conditions, in order that intelligent voltage schedules may be set up to govern their operation. With a view to making a general increase in voltage, it became desirable to make such a survey of Pittsburgh's downtown networks.

The 11-kv networks of the Duquesne Light Company are of the usual 4-wire, 3-phase type with protection provided by automatic secondary network protectors. Transformers are of 10 per cent inherent impedance with secondary voltage ratings of 115/199 volts. Primary transformer taps are provided for four 2½ per cent steps above secondary nameplate voltage. The equipment is now operating on the No. 1 tap which provides the greatest reduction ratio.

The voltage schedules under which the networks in question have been operating were set up a number of years ago, and with the exception of a few minor changes, have not been revised for some time. Load increases have caused changes in spot voltage conditions and a general increase in the range between maximum and minimum voltages throughout the networks.

It was felt that, if the prevailing conditions were accurately surveyed, steps could be taken to narrow the range between maximum and minimum voltages and the entire voltage schedule raised to provide the highest possible voltage consistent with good operation of 115-volt lamp equipment.

Load conditions on the networks are practically constant throughout the daytime hours, a condition which facilitated the gathering of voltage information. The typical network transformer loading is a daytime load starting to increase about 7:00 a.m., reaching its peak at 9:30 a.m. and, with the exception of a slight dip during the noon hour, remaining constant until approximately 4:00 p.m. A considerable drop takes place from 4:00 p.m. until 6:30 p.m., after which time load falls slowly until 2:00 a.m. and maintains a minimum until 7:00 a.m. the following morning. Such a load chart is shown in Fig. 1. This load condition is ideal for the securing of field data because of the large number of hours of constant load. The securing of this data was accomplished with crews made up of three men: a top man to watch the vault entrance, a man to handle the split core current transformer and voltmeter leads, and a third man to read meters and record data. Each crew was assigned a number of transformer banks such that they could complete the survey during the peak load hours and yet have ample time to make certain all readings were correctly taken. Twenty

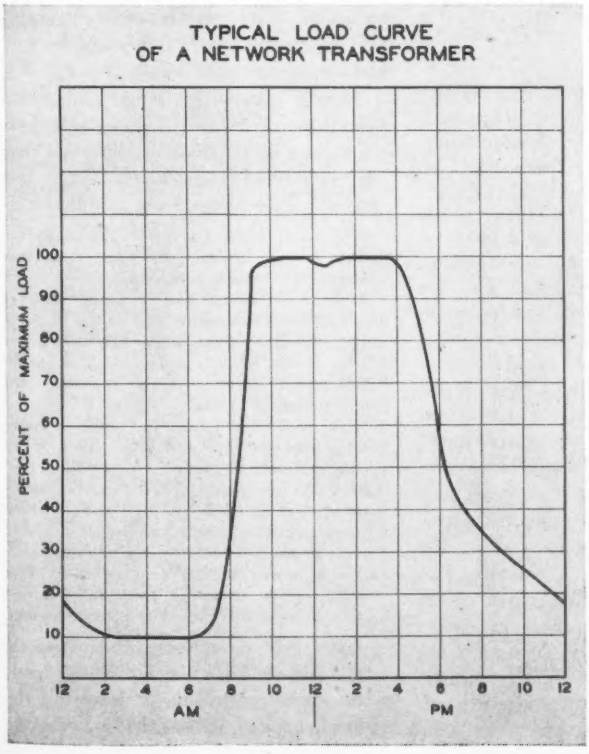


Fig. 1.

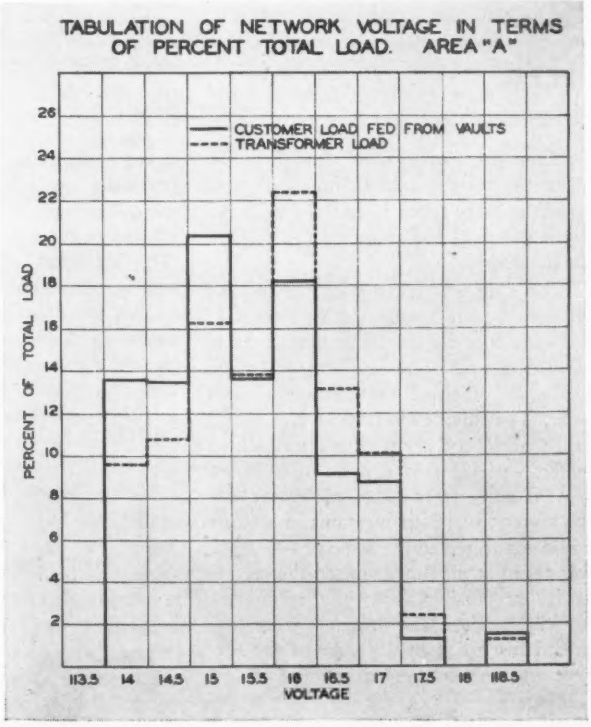


Fig. 2.

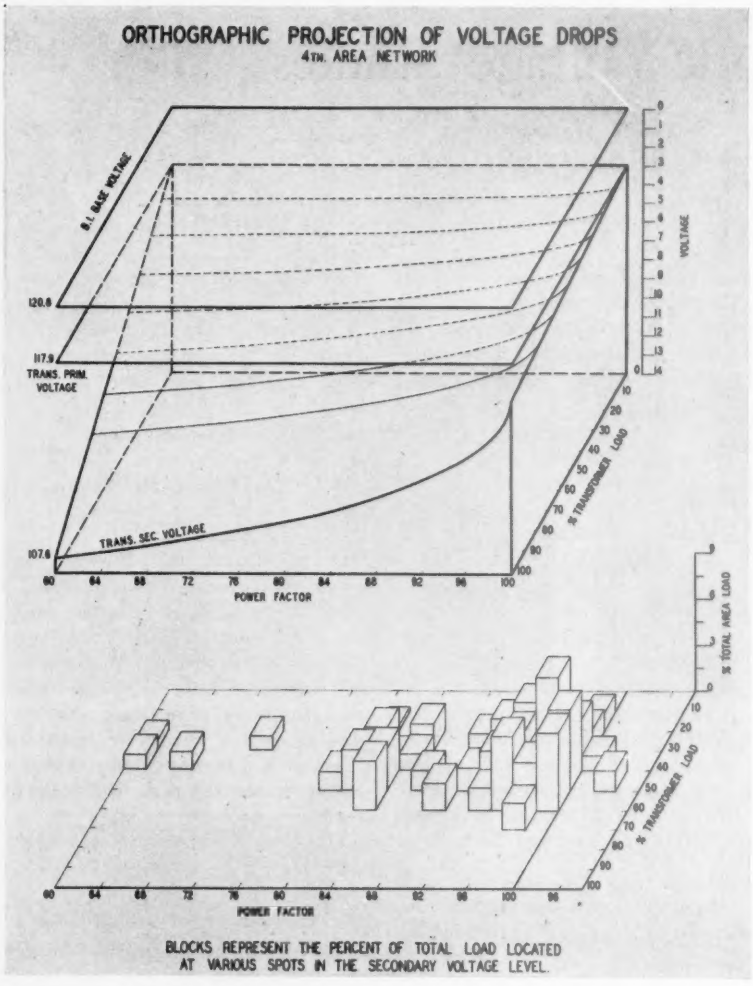


Fig. 3.

transformer banks were found to be about the correct number for each crew. Readings were taken from 9:40 to 11:45 in the morning and from 1:15 to 4:00 in the afternoon.

This data was taken with the following meters: one 5-ampere scale ammeter; one split core current transformer, ratio 1000/500 to 5; and one 150/300 volts full scale shielded voltmeter for each crew. The shielded voltmeter was found to be necessary as, with an unshielded meter, variations in voltage of as much as two volts were obtained by moving the meter to various locations in a vault while connected to the same phase. Care was taken at all times to keep the meters as far as possible from any equipment carrying load. All voltmeters were calibrated just prior to the start of the survey, and the corrections applied to all readings.

Readings were made of current on all three phases of the transformers, the street main cables, and of any load fed from the vault bus. Voltage readings were taken phase-to-phase and phase-to-ground at the top of the network protector. This point was chosen as being the nearest convenient approach to the transformer terminals. With the transformer and protector in separate compartments, to take the voltage readings at the transformer terminals would have necessitated a trip into the transformer compartment and would have slowed down the survey approximately one-third.

Voltage of the 11-kv networks is regulated by bus voltage control at the James H. Reed Power Station. The voltage is held at predetermined values by means of automatic generator voltage regulators, and changes in settings to conform to the predetermined schedule are made by hand. In making network voltage studies, it is extremely important that supply bus voltage data be available for comparison with field data, in order that voltage drops may be accurately determined. During the time of the test, extreme care was taken to see that the voltage was kept practically constant and that schedules were closely adhered to.

Because voltage drops are a function of power factor, as well as load, it was necessary to secure information as to phase angles of the loads on the individual transformer banks. Preliminary results obtained by actual measurement of the phase angle were found to compare very closely with the same results as taken from the power factor, load, and voltage curves for the particular transformer under consideration. Using the latter method, the power factor of all transformer loads was determined.

The load-voltage information for a typical network area, with all feeders in, is shown in Fig. 2, while the power factor load-voltage conditions for the same transformers is shown in orthographic projection in Fig. 3.

Fig. 2 indicates that the bulk of the customer's load fed directly from the transformer vaults falls in a band of 115 to 116 volts inclusive, while the total range is from 114.0 to 118.5 volts inclusive. There is a noticeable tapering off in the amount of the load at the higher voltage values.

A check of service entrance voltages on loads fed from street mains showed values of ½ to 1 volt below transformer voltage except where influenced by special conditions.

Fig. 3 shows the same loads with power factor information brought into the comparison. It will be observed that the individual transformer loads fall generally into four classes, as follows:

1. A small group having a leading power factor caused by the use of synchronous equipment or static condensers.
2. A large group having power factors above 90% with considerable range in loading of the individual banks. A number of banks in this group supply large loads to which power factor corrective measures had been applied previously.
3. A medium-sized group having power factors between 78% and 90%. This group is, in general, a number of smaller customers having predominating power loads whose power factor is not high and to which no corrective equipment has been applied.
4. A small, scattered group, lightly loaded, with power factors ranging from 60% to 72%. This group is principally power load using lightly loaded induction motors.

After analysis of such information, it is possible to study the individual loads with a view to raising or lowering the voltage supplied, so that the total voltage range for the entire network may be reduced and the voltage schedule read-

justed to give the highest average voltage commensurate with satisfactory service.

In view of the fact that it seemed desirable to raise the general voltage level to the highest possible values in order to provide reasonable voltage to as many customers as possible and, at the same time, not exceed permissible limits, it was thought desirable to make a study of a number of typical loads, particularly lighting, in order to see how large a percentage of the average customer's load was served at values near the supply voltage.

In making this survey, typical buildings were selected. Recording charts were taken of load and voltage at the source of supply to the building in order to establish a reference point. Indicating load and voltage readings were then made at the customer's distribution panels and lamp sockets on floors selected to give a representative cross section of the building voltage.

The results of this survey are shown in Fig. 4. This curve shows the voltage at the customer's distribution panels to be from 109 to 115.5 volts, with the average of approximately 112.5 volts.

A further drop will be experienced from the distribution panel to the lamp socket. The average of several readings proves this value to be from .1 volt to 5.0 volts, with the average value 1.5 volts.

A typical power station voltage schedule for a network area to give voltage conditions as shown in this report is as follows:

Voltage Schedule

Week days, except Saturday	Primary Bus Voltage	*Saturday*	Primary Bus Voltage
12:00 night	11,200	12:00 night	11,200
5:45 A.M.	11,250	5:45 A.M.	11,250
6:45 A.M.	11,300	6:45 A.M.	11,300
7:15 A.M.	11,350	7:15 A.M.	11,350
7:45 A.M.	11,400	7:45 A.M.	11,400
8:00 A.M.	11,500	8:00 A.M.	11,500
8:30 A.M.	11,550	8:30 A.M.	11,550
6:30 P.M.	11,500	2:00 P.M.	11,400
7:30 P.M.	11,400	9:00 P.M.	11,350
9:00 P.M.	11,350	9:45 P.M.	11,300
9:45 P.M.	11,300	10:10 P.M.	11,250
10:10 P.M.	11,250	11:45 P.M.	11,200
11:45 P.M.	11,200		
Sundays and Holidays			
All day	11,200		

Allowable primary voltage variation—100 volts plus or minus.

Conclusions and Recommendations

The laws of the State of Pennsylvania require that lighting voltage at the point of service shall not vary more than 5 per cent above or below the base voltage—in this case 115 volts, with limits of 109.25 and 120.75 volts.

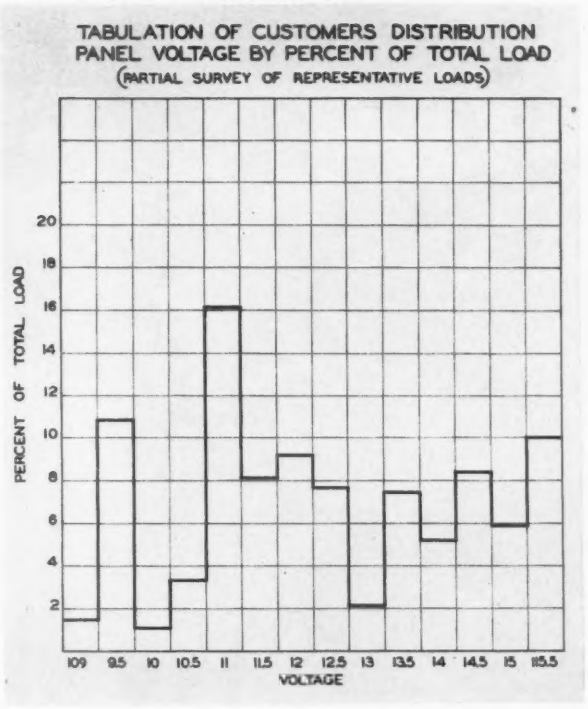


Fig. 4.

It will be observed from Fig. 2 that voltage supplied by the present schedule is between 114.0 volts and 118.5 volts. However, Fig. 4 shows that voltage supplied at the customer's distribution panels throughout buildings is between the limits of 109 volts and 115.5 volts, with approximately 84 per cent of the load below 115 volts. When it is considered that 115-volt lamps operate at maximum efficiency at 117 volts (see Fig. 5) it is realized that operation at the upper permissible range of supply voltage is certainly desirable. Allowing a plus or minus 1-volt variation in supply bus regulation, it will be observed that the voltage of the entire network area could be raised 1.25 volts immediately without exceeding the permissible limits of 120.75 volts for supply voltage.

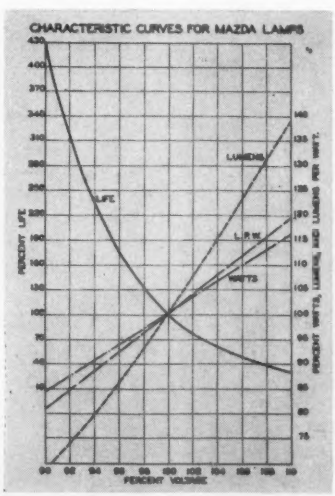


Fig. 5.

Further reduction in voltage of high voltage spots would permit a further increase in supply voltage and a corresponding rise in the remainder of the voltage range. An increase of the lower supply voltages would narrow the overall voltage range and result in better service to this group of consumers.

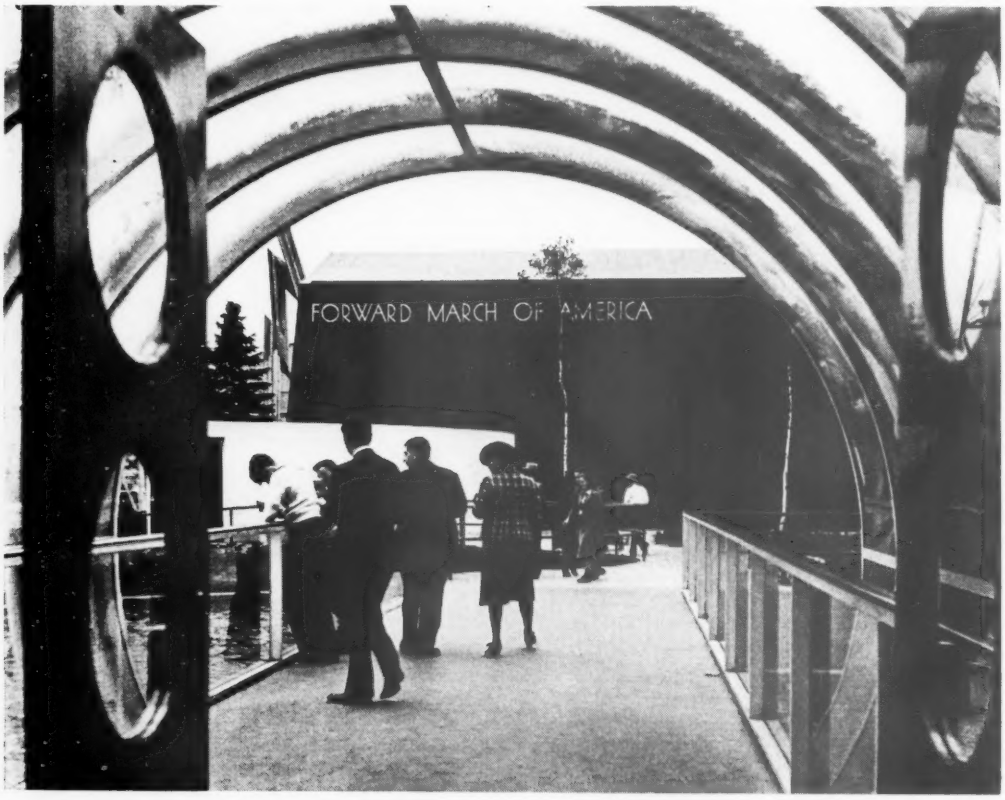
There are a number of methods which might be applied to accomplish these results. A brief description of these methods is as follows:

All of the high voltage areas are due to light transformer loads or over-application of corrective power factor equipment.

The first of these causes may be corrected by operating with the network switches of high voltage (lightly loaded) transformers normally open. Differential voltage relay settings of these switches could be made such that they would close to supply needed short circuit capacity in the event of secondary faults in the im-

(*Continued on page* 259)

Bell Telephone System Building, and, once more, Forward March of America!



Transformer Loading By the Statistical Method

By M. T. Crawford
Assistant Chief Engineer, Puget Sound Power & Light Company

A paper presented before the Transmission & Distribution Committee, Edison Electric Institute, Chicago, May 3-4, 1939

ADEQUATE field testing of distribution transformers is an expensive procedure, and only provides "spot" information as of the day of test. A number of years ago a scheme was used by a predecessor of the Puget Sound Power & Light Company for keeping a running record of the loading of distribution transformers in areas where they were banked together on secondary mains. This method made a record of the net additions to connected load on a large scale map, opposite the section of secondary mains adjacent to each transformer and included in its normal load area. This record was obtained from cut in line orders. Initial field tests of transformer loading were made with demand meters, from which a ratio of maximum demand to total connected load was obtained for each transformer area. This ratio was applied to revised values of connected load as obtained by posting the connects and disconnects from time to time. This plan was quite successful but was subsequently abandoned in favor of field testing.

During the recent depression, the need for economy prompted a proposal to revive the office method of transformer load supervision. The result was a new and improved method which uses customer meter readings instead of connected load data from line orders. This method was developed by Ray Rader, of this company, and may be briefly outlined as follows:

The normal load area of every distribution transformer is outlined on a copy of each circuit map. From the customer meter reading books a list of the customers within each transformer's load

Transf. No. L-888 Universal Map No. 254-88 Circuit No. 51

Customer Location Name or Address	Monthly Kwhr Consumption				Date Recorded	Equivalent No. of Customers					
	Res. Ltg.	Off-Peak Water Htg.	Comm. Ltg.	Power		Ltg., Class A	Ltg., Class B	Range	Off-Peak Water Htg.	Total Kv-a Req'd	Per Cent Loaded
2005-41st N	89				3-1-39	11	2	10	1	12.4	82.5
2009 "			175								
2010 "	206	350									
2015 "	244										
2033 "	226			57							
2037 "	220										
2048 "	140										
2053 "	193										
2056 "	605										
2063 "	419										
2069 "	156										

Fig. 1—Transformer loading record.

Example:

After the left-hand side of the transformer card has been filled out from the meter record, the data shown on the right-hand side is calculated as follows:

No. of Class A Equiv. Ltg. Cust.: Cust. at 2009 - 41st N. =	2
Cust. at 2033 - 41st N. =	2
No. of additional customers using under 400 kwhr per mo. =	7
Total Class A Ltg. Cust.	11
No. of Class B Ltg. Customers (over 400 kwhr per month)	2

No. of Equivalent Range Customers:

Records show that customer at 2056 - 41st N. has an on-peak water heater, and is therefore equivalent to two ranges.

Customers	2
All other range customers (those using over 100 kwhr. on Res. Ltg. schedule)	8
Total Equivalent Range Customers	10
Off-Peak Water Heaters	1
From Table I, 8 range customers and 1 off-peak water heater customer require in transformer capacity	7.5 kv-a
From Table II, 11 Class A Ltg. Customers require	2.3 kv-a
From Table II, 2 Class B Ltg. Customers require	2.6 kv-a
Total Kv-a Required	12.4 kv-a
Size of Transformer—15 Kv-a	
Per Cent Loaded	82.5 kv-a

area is made, and the highest monthly consumption in kwhr for each customer in the last 12 months is recorded on a loading card shown in Fig. 1. This is done twice a year or as often as desired.

The number of residential lighting customers or their equivalent, which contribute to the loading of each line transformer, is obtained from this record. The number of ranges and off-peak water heater customers is similarly recorded. Each 100 kwhr per month of commercial lighting or power is considered equivalent to one lighting customer, and each on-peak or manually controlled water heater is considered equivalent to one range customer. From the above data the total number of equivalent residential lighting, range and off-peak water heater customers is obtained for each transformer's load area, and the estimated maximum demand on the transformer is then obtained by reference to tables prepared for the purpose and recorded on a card form. These tables show the transformer capacity to be provided for various combinations of off-peak range, water heater, lighting and small appliance customers, and the transformer loading limits to be observed.

When the loading card indicates that the required transformer kv-a is in excess of a transformer's rated capacity, a field check is made and if this check indicates that the actual load on the transformer exceeds its carrying capacity, it is changed to one of larger size. When a transformer loading card shows that it is loaded below the allowable lower limit of loading as given in Table III, the transformer is removed or changed to one of smaller size.

During the recent depression years this scheme was used extensively to locate and reclaim underloaded transformers, as well as to determine the proper size transformer for new installations. A study of the distribution transformer loading on a number of urban residential feeders, with all distribution transformers banked, showed that the ratio of transformer capacity to the 15-minute demand on the feeders was seldom better than 2:1. After carefully following the load supervision procedure and eliminating the underloaded units, this ratio was improved to a maximum of about 1.5:1, and in many cases as low as approximately 1:1. On rural feeders with isolated transformers the ratio is usually much higher.

On this system there are over 45,000 distribution transformers of about 350,000

TABLE I—TRANSFORMER CAPACITY IN KV-A REQUIRED FOR RANGES AND OFF-PEAK WATER HEATERS

No. of Ranges	Transformer Capacity Required Kv-a										
10	8.4	8.4	8.4	8.4	8.9	8.9	9.5	10.1	11.2	12.8	13.3
9	7.9	7.9	7.9	7.9	8.4	8.4	8.9	9.5	10.8	12.2	12.7
8	7.5	7.5	7.5	7.5	7.9	7.9	8.5	9.1	10.3	11.7	12.2
7	7.0	7.0	7.0	7.0	7.4	7.4	8.1	8.7	9.7	11.1	11.7
6	6.5	6.5	6.5	6.5	6.9	6.9	7.7	8.3	9.3	10.5	11.0
5	6.1	6.1	6.1	6.1	6.4	6.4	7.3	8.0	9.3	9.7	11.0
4	5.6	5.6	5.6	5.9	5.9	5.9	6.9	7.7	9.3	9.7	11.0
3	5.1	5.1	5.1	5.4	5.4	5.6	6.4	7.7	9.2	9.7	11.0
2	4.3	4.3	4.3	4.5	4.8	5.5	6.4	7.7	9.2	9.7	11.0
1	2.2	3.0	3.0	3.8	4.6	5.4	6.4	7.7	9.2	9.7	11.0
0	0	1.5	2.3	3.8	4.6	5.4	6.4	7.7	9.2	9.7	11.0
	0	1	2	3	4	5	6	7	8	9	10

Number of Off-Peak Water Heaters

TABLE II—TRANSFORMER CAPACITY IN KV-A REQUIRED FOR LIGHTS AND APPLIANCES OTHER THAN RANGES AND OFF-PEAK WATER HEATERS

No. of Customers	1	2	3	4	5	6	7	8	9	10	11	12
Kv-a Required:												
1. Class A Res.	.35	.55	.83	.97	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.5
2. Class B Res.	2.0	2.6	3.4	4.1	4.8	5.4	6.0	6.5	7.0	7.5	7.9	8.3
No. of Customers	13	14	15	16	17	18	19	20	21	22	23	24
Kv-a Required:												
1. Class A Res.	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.1
2. Class B Res.	8.7	9.1	9.5	9.9	10.3	10.7	11.1	11.5	11.9	11.9	12.7	13.1

Explanations for Table II:

1. Class A Residence consists of 4-room houses or smaller, with lights and small appliances only.
2. Class B Residence consists of 6-room houses or larger, with practically all types of appliances, or which uses over 400 kwhr per month, exclusive of off-peak water heater.
3. Kv-a required for medium grades of residences can be obtained by interpolation.
4. Table II does not include on-peak or manually controlled water heaters. These heaters should be considered equivalent to a range, and the requirements obtained from Table I.
5. When the requirements for a group of Class A Residences are added to a group of Class B, the result will be slightly high due to diversity.

TABLE III—TRANSFORMER SIZES TO USE FOR NEW LOADS AND IN THE REPLACEMENT OF OVERLOADED OR UNDERLOADED TRANSFORMERS

Transf. Size to Use, Kv-a	Range of Kv-a Applicable to a Given Size of Transformer					
	Medium to Rapid Growth Area			Slow Growth or Dormant Area		
	Upper Value of Transf. Kv-a Req'd by the Load	Lower Value of Transf. Kv a Req'd by the Load	Lower Value of Kv-a Req'd in percent of Transformer Rating	Upper Value of Transf. Kv-a Req'd by the Load	Lower Value of Transf. Kv-a Req'd by the Load	Lower Value of Kv-a Req'd in percent of Transformer Rating
1.5	1.0	....	....	1.5	....	....
3	2.7	....	....	3.0	....	....
5	4.5	2.7*	54	5	3*	60
7.5	6.8	4.5*	60	7.5	5*	67
10	9.1	6.8*	68	10	7.5	75
15	13.7	9.1	60.5	15	10	67
20	18.2	13.7	68.4	20	15	60
25	22.5	13.7	54.8	25	15	67
37.5	34.0	22.5	60	37.5	25	75
50	45.5	34.0	68	50	37.5	75
75	68.2	45.5	60.6	75	50	67
100	91.0	68.2	68.2	100	75	75
150	137	91	60.6	150	100	67
200	182	137	68.4	200	150	75

* These values apply to new installations only.
Transformers rated at 10 kv-a or less should not be replaced due to underload unless the kv-a required is less than 50% of the transformer rating.

How to Use Table III—When the transformer kv-a actually required to serve a given load has been determined as outlined, refer to Table III and determine within what range of kv-a the required kv-a falls. The transformer size to use is found in the first column, opposite the range of kv-a.

Example I. A 25 kv-a transformer serves a load requiring only 8.4 kv-a of transformer capacity, in a territory of medium load growth. Referring to Table III, the smallest load to be served by a 25 kv-a transformer is one that requires 13.7 kv-a of transformer capacity. Therefore, the 25 kv-a transformer in question should be replaced with a smaller size. By further inspection of the table it is seen that a load requiring 8.4 kv-a of transformer capacity lies within the range of a 10-kv-a transformer, which is, therefore, the size to use.

Example II. A group of customers in a medium load growth area are to be served from a single transformer and the actual kv-a required to serve has been determined by means of Table I and Table II to be 8.4 kv-a. Inspection of the table shows that this load falls within the range of a 10 kv-a transformer, which is, therefore, the size of use.

TABLE IV—ALLOWABLE AVERAGE PEAK DEMANDS ON DISTRIBUTION TRANSFORMERS IN PER CENT OF TRANSFORMER RATING

To be used as a guide in loading transformers where load charts have been taken in the field

Duration of Peak Demand	Recurrent Loads		Emergency or Rare Loads	
	Following Full Load	Following Light Load	Following Full Load	Following Light Load
1 Minute	.....	.....	475%	604%
5 "	174%	280%	280%	350%
15 "	160%	220%	.....	.....
30 "	146%	185%	.....	.....
1 Hour	138%	160%	.....	.....
2 "	128%	140%	.....	.....
5 "	117%	120%	.....	.....

Emergency loads are short time overloads, unexpected and of infrequent occurrence. Recurrent loads may be premeditated and more or less frequent, such as daily peaks. The values in the table are based on an ambient temperature of 30°C (86°F), and are applicable to all Western Washington and for Winter Peaks in the Eastern District. For Summer Peaks in the Eastern District, reduce the above figures 10 per cent.

kv-a capacity, representing an investment of around $5,500,000. The cost of setting up an office method for this system as outlined above is estimated at a little over $12,000 for the first year and about $3,600 per year thereafter. Preliminary figures from partial operation of this scheme indicate that under present load conditions a total of over $800,000 worth of idle transformer capacity might be reclaimed from this distribution system at a cost of approximately $55,000 for setting up the record system, removing the underloaded units, and installing smaller transformers when necessary.

If the depression loss of load should be regained, all of this saving would not be realized, but a continuous saving will be effected by the practice of making new transformer installations of minimum necessary capacity instead of providing excess capacity due to lack of information. These savings will depend on the extent to which the previous practice has provided excess capacity. If the scheme permits a decrease of 15 per cent in transformer purchase requirements for load increase, it would result in an annual saving of $60,000. The same results and savings could be effected by close load supervision by field testing methods, using recording meters and frequent spot checks, but at a probable annual cost of approximately $90,000 for the 45,000 transformers.

Besides its economy, an office statistical method has the advantage of furnishing a means of obtaining an up-to-date load record at frequent intervals, and will catch local load changes in time to permit reasonably prompt work of reclaiming excess capacity or relieving overloads. For any particular distribution system, the most economical combination of office record and field testing can be worked out which will provide the desired closeness of load supervision.

The accompanying tables, instructions and examples are taken from the company's Standard Practice Manual.

Copies of a Price List
of publications
of the Institute
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EDISON ELECTRIC INSTITUTE
420 Lexington Avenue
New York, N. Y.

Network Voltage Studies

(*Continued from page 255*)

mediate vicinity. This is further facilitated by the use of limiters and a supervisory system now in use which gives automatic indication of network switch position. Replacement of present transformer units with smaller units as a means of reducing voltage is also being studied.

High voltage caused by incorrect application of power factor corrective equipment by customers may be corrected by co-operative action with the customer.

Low voltage areas may be improved by one or more of the following methods:

1. Application of power factor corrective equipment to loads having poor power factor and resulting excessive voltage drops.

2. The use of 5 per cent transformers to supply heavy spot loads where present transformers are loaded above the average transformer loadings. Further study is being made of this method.

3. The removal of syn bus reactors in multiple-unit vaults which will result in more equal distribution of load on the transformers in the vault. This method is limited to multiple-unit vaults where power equipment starting currents will not introduce objectionable lighting voltage variations, with the reactors removed. In such cases, study of starting equipment may be indicated.

4. Reinforcing of secondary main copper where loads are in excess of average street main loads.

All of the above solutions are, of course, subject to economic study before their final acceptance. Without applying any of the corrective measures described, it is possible to increase the present daytime voltage schedule by 1.25 volts and not exceed the permissible maximum value of 119.75 volts plus 1 volt bus regulation allowance. This would still leave all of the customers' distribution panel voltages shown in Fig. 4 below 117 volts. Further advance in voltage schedule could be made as maximum spot voltages were reduced.

Two small networks serving approximately 7500 Kva of load have been operating at the maximum permissible voltage schedule for three months without a single customer complaint or, as far as is known, a change in lamp voltage rating on the part of any customer.

The author is indebted to Mr. C. U. Thomas and Mr. H. C. Richardson for assisting in the gathering and preparation of data for this paper.

Design of Substations From the Point of View of Accident Prevention

By G. S. Diehl and B. Van Ness, Jr.
Pennsylvania Water & Power Company

A paper presented in a symposium at Joint Meeting of the Accident Prevention Committee and the Electrical Equipment Committee, E.E.I., Chicago, May 1, 1939

A DISCUSSION of the relation between Substation Design and Accident Prevention might well approach the problem from two standpoints:

(1) Elimination of "accidents" to personnel.

(2) Elimination of "accidents" to service.

The same need for initial "size up" of connections and physical arrangement applies to the operator in the control rooms as to the maintenance man actually working on the equipment. For this reason, the designer should keep in mind requirements of simplicity and symmetry when laying out equipment.

The Pennsylvania Water & Power Company is essentially a generating and transmission company, therefore, the majority of our substations are of the step-up bulk power type. This is particularly true of the stations erected in the past 10 years. We are, therefore, somewhat limited in our field of discussion of the subject but we feel that we would like to point out a few of the safety features which we endeavor to incorporate in our design.

In our 13,200-volt indoor substations we have long been faced with the problem of positive circuit identification in locations where circuit boundaries are not obvious. As early as 1920 we adopted the use of vividly painted markers to indicate the confines of an electrical circuit (Fig. 1). This is still carried out today but as a supplement to more carefully located and completely interlocked structures.

In one station where hook stick disconnectors are used, the compartment doors, equipped with large wire glass panels to permit observation of switch positions, either cover or uncover, as a unit, the three phases of a circuit (Fig. 2).

Our older outdoor high-tension installations have been relatively simple to

Fig. 1, left—Barrier markings at Highlandtown substation.

Fig. 2, above—Compartment doors—Holtwood—open.

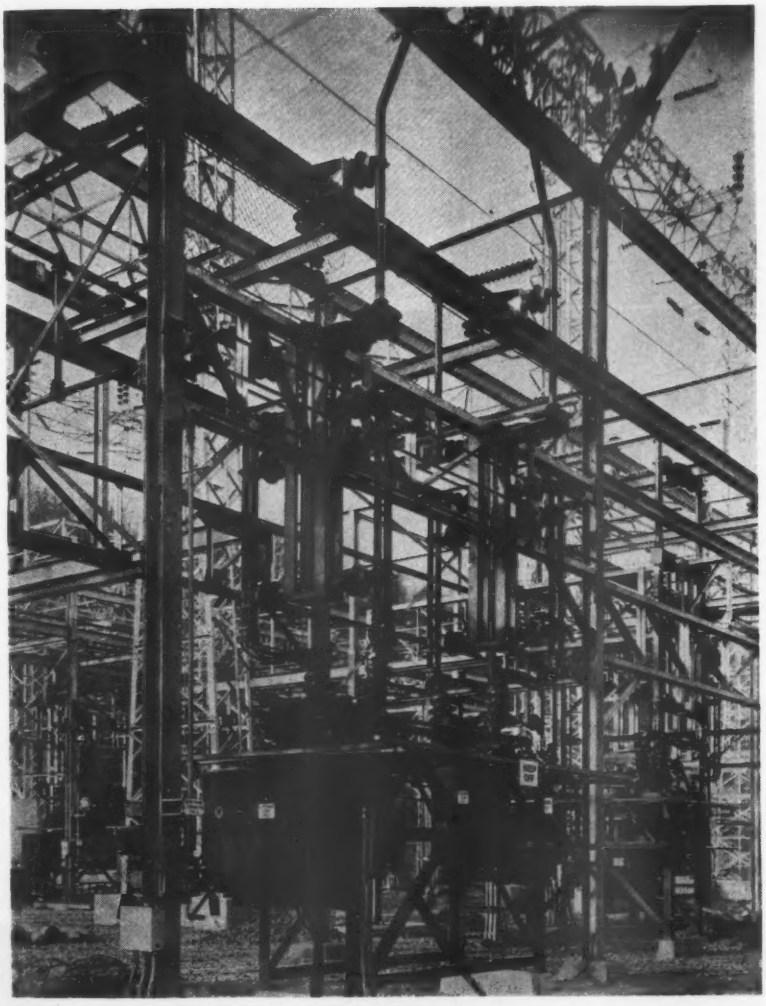


Fig. 3—Low tension oil circuit breaker—Conestoga substation.

isolate, because of the unit transformer-circuit construction with firewalls between bays. In infrequent cases where unit construction must be violated by the passage across natural barriers of an extraneous circuit—for example, where the "hot" connection of a transformer neutral to a Peterson coil passes another transformer—the extraneous circuit is completely screened or shielded. One difficulty has been to separate high-tension circuit air break switches; a simple and easily erected red pipe barrier is now used to separate circuits.

With our past experience and the experience of others as a background, we are employing the following general principles in our newer substation design:

1. The use of unit transformer-line construction where possible for high-voltage connections.

2. Where buses are required in substations, we are using a single bus of several sections, with each circuit of duplicate services connected to a different bus section through a single oil circuit breaker. In step-up substations important machines may be connected to more than one bus section.

3. Every effort is made to make circuit definition sharp and connections easy to visualize.

4. Isolation of individual circuits and associated equipment is obtained by location, separation and elevation and by enclosure where the foregoing are not possible.

5. All disconnecting, air break and grounding switches are gang operated. The poles of oil circuit breaker isolating switches, on both sides of the breaker, operate from one mechanism and ground the breaker in the open position.

6. All normal circuit grounding in stations is accomplished through gang operated grounding disconnectors.

7. The Cory lock system is employed to completely interlock the station and to require definite sequence of operations.

8. Grounded platforms are used out of doors at all manually operated mechanisms. We connect switch base steel to the operating mechanism and to ground with a continuous copper connection and out of doors this connection also ties to the grounded platform.

9. Our designs are checked with Operating and Safety Departments before construction is started.

Fig. 3, taken during construction, shows a transformer oil circuit breaker on the low-tension bus of our latest substation and is indicative of the general low-tension construction we employ outdoors. The gang operated mechanisms can be observed together with the breaker isolating disconnector with blade open and in the grounded position and the gang operated transformer low-tension grounding switch in the closed position. Isolation of this transformer circuit from the main bus by screen will be noted in this picture.

Fig. 4 shows the construction of one of our 230-kv switching stations. The isolated type structure employed in this and our other 230-kv lend themselves to clear circuit definition.

Our Operating Department has been very insistent that we provide walkways

Fig. 4—Ellicott switching station.

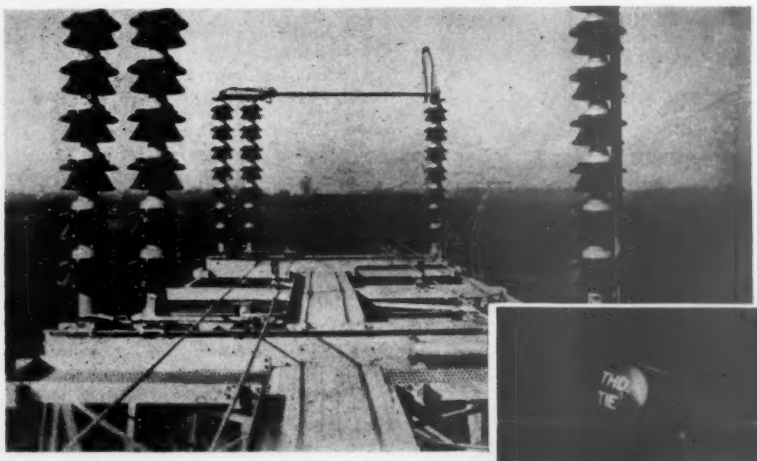


Fig. 5—Walkways—Ellicott substation.

for maintenance of our air break switches (Fig. 5). The walkways to each switch are served by an individual ladder and to prevent accidental communication to the adjacent circuit walkways do not carry over to the adjacent circuit. Sockets are provided for temporary guard rails.

Mr. Wallau has suggested that the use of variously shaped and colored control switch handles as an aid to operation be discussed. This type of marking has been employed on our system for some years (Fig. 6). In our newer stations we use:

Black pistol grip	Oil circuit breaker
Red pistol grip	Air break switch
Red oval	Ground switch
Black oval	Low voltage air circuit breaker
Black notched	Voltmeter, etc.
Red notched	Voltage regulator, field rheostats

These switches have the equipment

(*Continued on page 272*)

Fig. 6—Tie control switch—Safe Harbor.

Fig. 7—Night view—Conestoga substation.

Neutral Conductors for Underground Distribution Circuits

By W. R. Bullard
Ebasco Services Inc.

A paper presented before the Transmission and Distribution Committee, Edison Electric Institute, Chicago, May 3-4, 1939

AT the meeting of the Subcommittee on Underground Methods and Accessories, held at Rochester, N. Y., February, 1939, there was considerable discussion concerning the use of bare neutral conductors in underground distribution systems. It appeared that there was an astonishing lack of agreement between utility engineers as to the practicability of using bare conductors without incurring serious consequences from corrosion, and other undesirable effects such as pitting or burning lead sheaths of cables in contact with bare neutral under short-circuit or other abnormal electrical conditions. This, therefore, was selected as a subject for discussion at the present meeting of the Transmission and Distribution Committee under the auspices of the Underground Group, and the writer was asked to collect some information on the subject and present it at this meeting.

Without attempting to make a complete survey of existing practices, a number of companies, believed to represent a reasonable cross section of the practices of the country, were contacted. Of these, 19 furnished brief information relative to their practices and experience, all of which is summarized herewith. To cover the subject fully, a considerable amount of additional data would be needed, including analysis of bonding practices, local conditions regarding moisture and chemicals encountered in the conduit systems, and local conditions regarding electrolysis. However, it is hoped that the limited amount of data presented will be found interesting and helpful.

It appears from the information furnished that the use of bare neutrals predominates, with weatherproof-covered neutrals next in degree of use, and with insulated neutrals the least used. By bare neutrals is meant either bare tinned or untinned copper or insulated lead-covered copper.

Preferred or general practices, with respect to neutrals of primary and secondary mains were reported as follows (See item "C" of the summary):

5 companies made no mention of general or preferred practice;

2, as general practice, use bare tinned copper in the same ducts as lead-covered phase conductors (one of these is a large metropolitan company);

2, as general practice, use bare untinned copper not in the same ducts;

2, as general practice, use bare tinned copper not in the same ducts;

1, as general practice, uses both bare tinned in the same ducts, and bare untinned not in the same ducts;

4, as general practice, use weatherproof-covered neutrals in the same or not in the same ducts as the lead-covered phase conductors.

1, as general practice, uses uninsulated lead-covered copper in the same ducts.

Only 2 companies reported as general practice, the use of insulated lead-covered neutrals.

It will be noted from the preceding that bare tinned copper is more widely used than untinned, and that the latter represents a preferred practice only when not in the same ducts with insulated lead-covered phase conductors. However, six companies indicated the use, on a small scale, of untinned copper in the same ducts with lead-covered cables. (See item "D" of the accompanying summary.) The experiences reported for such installations in some cases were satisfactory, and in others, unsatisfactory. Only one company reported serious cases of corrosion. Two reported cases in which the lead sheaths were burned where in contact with the neutral. Two companies reported mechanical damage to lead sheaths during installation, due to the presence of the bare neutral. Of course, this latter has no bearing on the matter of tinning.

One factor in the selection of tinned in preference to untinned copper is that splicing is made easier because a slight amount of surface corrosion of the untinned neutral requires careful cleaning before a splice is made. The fact that a large metropolitan company has made it general practice for many years to install bare tinned copper in the same ducts with lead-covered cables with satisfactory results, should be given due weight in connection with the questions of corrosion and damage to lead sheaths by fault currents. This company formerly used untinned copper, but changed to tinned to facilitate splicing and to avoid the slight amount of corrosion experienced.

Experience with both tinned and untinned copper not in the same ducts as lead-covered cables is indicated as satisfactory by all companies reporting on these types.

The use of weatherproof-covered copper is governed in some cases by the additional protection afforded, and in others, largely by the availability of this type of conductor because of its use in the overhead system, and the desire to simplify stocking of materials. Experience with its use, either in the same or not in the same ducts as lead-covered cables, was indicated as satisfactory in all cases.

Experience with the uninsulated lead-covered copper also was reported as satisfactory.

One company reported a recent installation of solid soft-drawn 4/0 bare untinned copper in separate ducts, and stated that the installation of this solid wire was not found to be difficult.

Several companies reported the use of one or more types of neutrals buried in the concrete envelope of the conduit system or underneath the concrete envelope. These cases are included in the items termed "not in same duct as lead-covered cables."

All the data are summarized in somewhat greater detail in the following:

NEUTRAL CONDUCTORS

Summary of Practices and Experiences Reported by 19 Companies

A—Number of Types of Neutral Conductors in Use by Individual Companies

3 companies reported use of one type.
8 companies reported use of two types.
6 companies reported use of three types.
2 companies reported use of four types.

B—Number of Companies Using Each Type

6—bare untinned copper in same duct with lead-covered phase conductors.
9—bare untinned copper not in same duct with lead-covered phase conductors.
3—bare tinned copper in same duct with lead-covered phase conductors.
1—bare tinned copper in same duct with non-leaded phase conductors.
2—bare tinned copper not in same duct with lead-covered phase conductors.
7—weatherproof-covered copper in same duct with lead-covered phase conductors.
5—weatherproof-covered copper not in same duct with lead-covered phase conductors.
2—weatherproof-covered copper but not stated whether in same, or separate duct, from lead-covered phase conductors.
6—lead-covered insulated copper.
1—abandoned Edison tube.
1—salvaged lead-sheathed cable.
2—non-insulated lead-covered copper.

C—Preferred Practices (figures indicate number of companies)

1—bare untinned copper not in same duct with lead-covered phase conductors.
1—bare tinned in separate duct for mains, weatherproof copper in same duct for services.
2—bare tinned copper in same duct.
1—lead-covered uninsulated copper in same duct.
1—bare tinned copper in separate duct.
1—weatherproof copper in separate duct for mains, bare untinned copper in same duct for cable risers and services.
2—weatherproof-covered copper in same duct.
2—lead-covered insulated copper.
1—weatherproof-covered copper, but not stated whether in same, or separate duct.
1—bare tinned copper in same duct and bare untinned copper not in same duct for mains, and weatherproof-covered copper for pole risers when using non-leaded phase conductors.
1—bare untinned copper not in same duct for mains, bare tinned copper in same duct for services. No standards yet, but making studies as to necessity of tinning.
5—no mention of standards or preferred practice.

D—Experience with Bare Untinned Copper in Same Duct with Lead-Covered Phase Conductors—6 Usages (see "B")

1 company—a few installations, with no difficulties.
1 company—bare stranded neutral (4/0) damaged lead sheathing during installation. In case of cable failures, melted lead in contact with bare neutral and maintained arc.
1 company—no trouble with corrosion.
1 company—bare neutral damaged lead sheating during installation. No knowledge of corrosion, but not sure what has taken place in duct runs out of sight.
1 company—not cognizant of corrosion; conduits are dry, well drained. Now considering using tinned or other protected neutral with rubber-insulated cables, because do not consider satisfactory to install bare untinned neutral in same duct with phase conductors.
1 company—negligible amount installed—one or two cases of corrosion—one or two cases where lead sheaths were burned when in contact with bare neutral. Has small amount bare neutral on a small spot network in dry ducts, installed for seven years, with no corrosion or other troubles.

E—Experience with Untinned Bare Copper not in Same Duct with Lead-Covered Conductors—9 Usages (see "B")

1 company—no experience to indicate necessity for tinning.
1 company—corrosion and oxidation resulted in difficulty of making soldered connections for bonding and branch extensions.
1 company—installed to provide continuous copper neutral under fault conditions—no difficulties.
1 company—no serious corrosion, however, some corrosion of lead sheaths attributed to electrolysis or impurities in lead.
1 company—satisfactory—conduits dry and well drained.
1 company—on d-c underground system, holding up very well and giving good service.
1 company—satisfactory to date—from experience do not dare install entirely bare copper neutral in contact with lead sheath.
1 company—some installed in 1938—not aware of corrosion to date.
1 company—experience satisfactory. One installation in service for 24 years. Is satisfactory except copper is quite green.

F—Experience with Bare Tinned Copper in Same Duct with Lead-Covered Conductors—3 Usages (see "B")

1 company—used to safeguard against corrosion to lead sheath. However, no experience to indicate necessity for tinning.
1 company—tinning improves end and tap connections. No troubles where entirely bare copper used. Sees no need for braided covering.
1 company—experience satisfactory. Bare untinned copper used at one time but changed to bare tinned to facilitate splicing due to slight corrosion on bare untinned.

G—Experience with Bare Tinned Copper not in Same Duct with Lead-Covered Conductors—2 Usages (see "B")

1 company—used for last 10 years. Experience satisfactory.
1 company—recent installations. Purpose of tinning is to avoid galvanic action in acid soil.

H—Experience with Uninsulated Lead-Covered Copper—2 Usages (see "B")

2 companies—both satisfactory.

I—Experience with All Types of Neutrals Insulated or with Non-Metallic Protection—21 Usages (see "B")

All satisfactory.

Prime Movers Committee

(*Continued from page 234*)

committee the results of his questionnaire covering vibration and noise problems with the larger size 3600 rpm turbo-generators. Mr. Drummond reported on the heater section of the Turbine report.

Resolution on Dr. Hirshfeld

Chairman Caldwell appointed a special committee, consisting of Professor Christie, Dean Potter and Mr. Daniels, to draft a memorial tribute to the late Dr. C. F. Hirshfeld. The resolution was later presented, adopted and the secretary was directed to spread upon the record and transmit copies of the resolution to Mrs. Hirshfeld and Mr. Alex Dow.

The Resolution follows:

The Prime Movers Committee of the Edison Electric Institute at its meeting in Chicago, Illinois, May 1 and 2, 1939, has learned with deep sorrow of the passing on April 19, 1939, of its former Chairman and close friend of many of its members, Dr. Clarence Floyd Hirshfeld.

Dr. Hirshfeld, internationally known as an engineer, as a creator of new knowledge, and an educator, organized the first research department in an electric power utility, was responsible for revolutionary advances in the field of electric traction, and through his lectures and writings brought about a clearer appreciation of the relation of the engineer to Society.

Dr. Hirshfeld devoted the first ten years of his professional career to teaching at Cornell University and his continued interest in educational problems culminated in the development, under his leadership, of the Engineers Council for Professional Development, an instrumentality for the enhancement of the professional status of the engineer.

Dr. Hirshfeld exemplified the finest attributes of the engineer through the clarity of his thinking, his unbiased analysis, his power of expression and his courageous actions in support of his conclusions.

The engineering profession and particularly the electrical power industry has suffered an irreparable loss through the untimely passing of this distinguished engineer and leader.

The Prime Movers Committee of the Edison Electric Institute records at this time its sincere appreciation of his fruitful life and outstanding contributions."

Signed: Prime Movers Committee
Edison Electric Institute

Mr. Hopping presided over the Round Table discussions and disposed of many of the problems previously listed by members for consideration.

The meeting adjourned at noon to permit members to participate in inspection trips.

A Small Outdoor 110 KV Substation

By H. B. Robinson
Carolina Power & Light Company

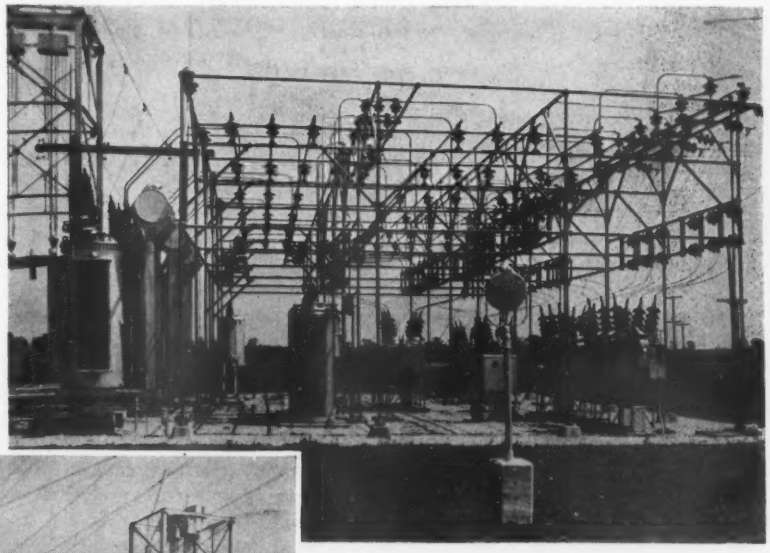
A paper presented before a meeting of the Electrical Equipment Committee, E.E.I., Chicago, May 2, 1939

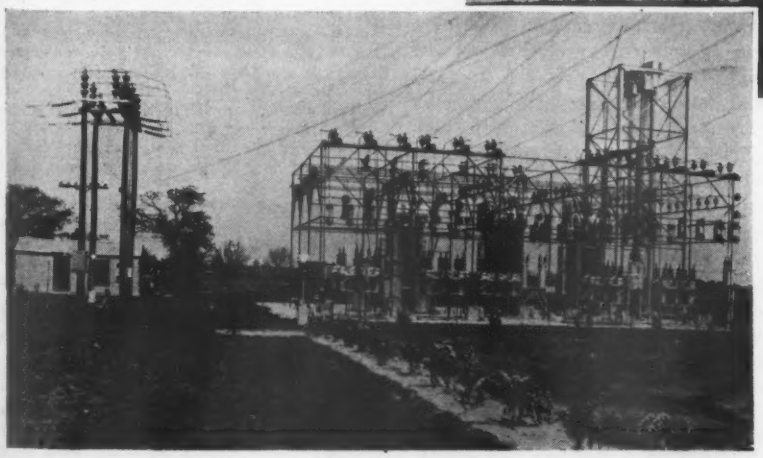
AFTER other papers that have been presented describing substations, it was felt that the above title would be very fitting for a substation recently built on our system near the town of Florence, S. C. By comparison with the substations previously described, it is just a large station service bank and it will probably be hard for some to realize that substations of this size are still being built in this country.

Our system is primarily a hydroelectric system and covers a low density territory from the North Carolina-Virginia line through North Carolina and half-way through South Carolina. It is approximately 200 miles long and 75 miles wide. We have approximately 49 miles of 132-kv single circuit, 376 miles of 110-kv. double circuit, 370 miles of 110-kv single circuit, 436 miles of 66 kv, 103 miles of 33 kv, and 443 miles of 22-kv lines, or a total of 1777 miles of lines 22 kv and above. We have 323,000 kv-a in step-up transformers, and 490,000 kv-a in step-down transformers (22 kv and above), and 184,000 kv-a in transformers interconnecting our system with adjacent systems. We have 16 interconnections with adjacent systems. Our primary step-down substations, 110 kv and above, vary from approximately 32,000 kv-a to 3750 kv-a.

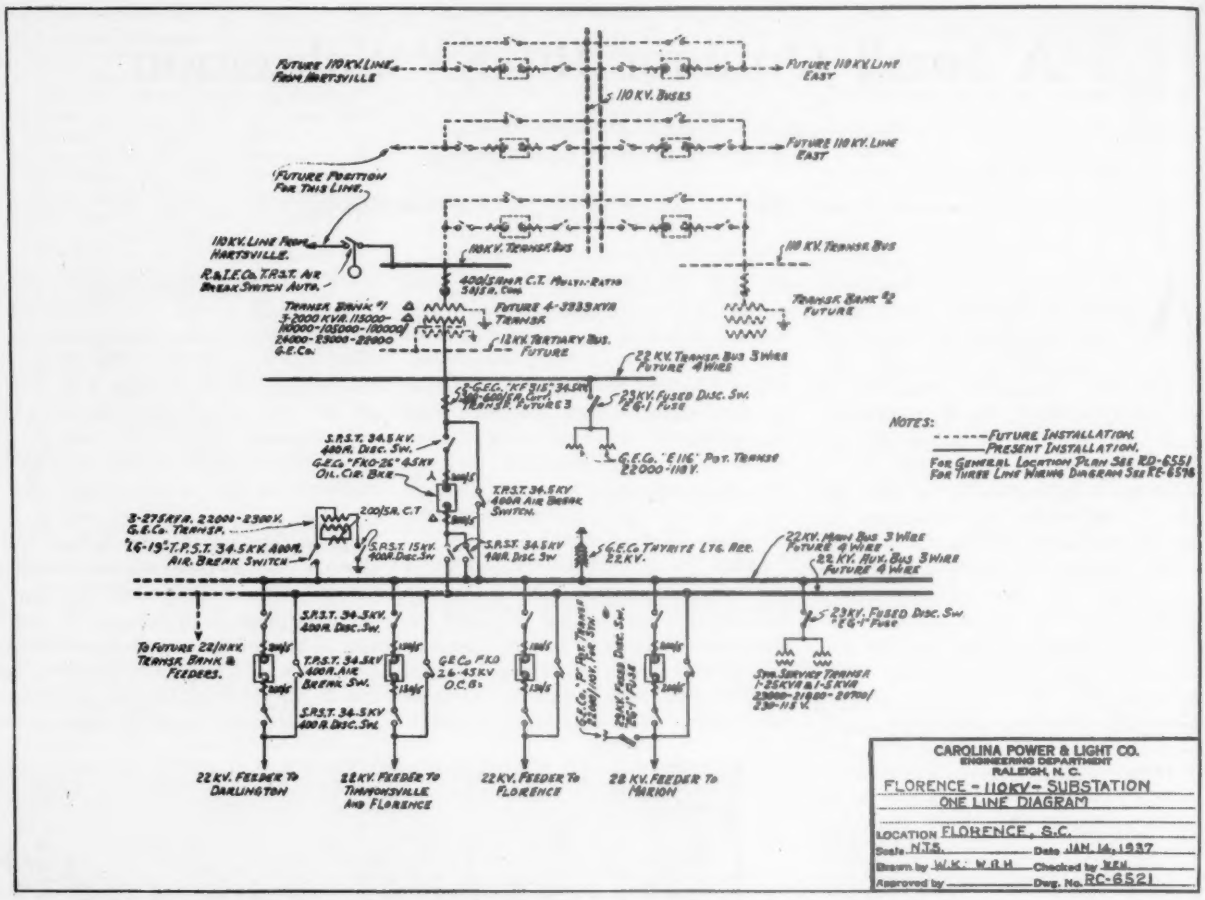
The Florence substation was built to furnish an additional feed to 100 miles of 22-kv line which was supplied from primary stations at both ends and which had a peak load of approximately 11,000 kw. A 5000-kv-a synchronous condenser is located about mid-way between the two supply stations, but, even with the condenser, the load could not be satisfactorily carried from one end only. This new substation is not at the load center of the line, but is near the most important load fed by this line.

When we received approval to build this substation, it was with the understanding that the cash out of pocket expenditure would be as low as practical, so a good portion of the equipment and material used were from other parts of our system. The transformers, which are 22 years old, were originally rated 100 kv to 22 kv and were rebuilt with modern high- and low-voltage windings rated 110 kv to 22 kv. The oil circuit breakers are old G. E. type F.K.O. 26. 45 kv, with interrupting capacities of approximately 100,000 kv-a, which interrupting capacities are only slightly in excess of the duty to which these breakers may be subjected. It was recognized at the time this station was built that the load on the transformers would probably exceed their rating within a period of four or five years, at which time a larger bank together with larger breakers would have to be installed, but due to the unsettled business conditions, it was felt that it would be wise to use





Two views of the station about 18 months after completion. This station was designed and constructed by the company's forces during 1937. A crew of nine men were used on construction.


FUTURE 110 KV. LINE FROM HARTSVILLE
FUTURE 110 KV. LINE EAST
110 KV. BUSES
FUTURE 110 KV. LINE EAST
FUTURE POSITION FOR THIS LINE.
110 KV. LINE FROM HARTSVILLE.
110 KV. TRANSM. BUS
110 KV. TRANSM. BUS
R.&I.E.Co. T.P.S.T. AIR BREAK SWITCH AUTO.
400/5 AMP. C.T. MULTI-RATIO 5 MT. B. Conn.
TRANSM. BANK #1
3-2000 KV.A. 115000-110000-105000-100000/24000-23000-22000 G.E.Co.
FUTURE 4-333.3 KV.A. TRANSR.
TRANSR. BANK #2 FUTURE
12 KV. TERTIARY BUS. FUTURE
22 KV. TRANSR. BUS 3 WIRE FUTURE 4 WIRES
3-G.E.Co. "KF 315" 34.5 KV. 300-600/5 A. Curr. TRANSF. FUTURE 3
23 KV. FUSED DISC. SW. 25-1 FUSE
NOTES:
------FUTURE INSTALLATION.
——PRESENT INSTALLATION.
FOR GENERAL LOCATION PLAN SEE RD-6551
FOR THREE LINE WIRING DIAGRAM SEE RE-6516
S.P.S.T. 34.5 KV. 400 A. DISC. SW. G.E.Co. "FKO-25" 45 KV. OIL CIR. BKR.
G.E.Co. "E 116" POT. TRANSR 22000-110 V.
200/5 A. C.T.
S.P.S.T. 34.5 KV. 400 A. AIR BREAK SWITCH.
3-275 KV.A. 22000-2300 V. G.E.Co. TRANSR.
16-19 T.P.S.T. 34.5 KV. 400 A. AIR BREAK SWITCH
S.P.S.T. 15 KV. 400 A. DISC. SW.
S.P.S.T. 34.5 KV. 400 A. DISC. SW.
G.E.Co. THYRITE LTG. ARR. 22 KV.
22 KV. MAIN BUS 3 WIRE FUTURE 4 WIRE
22 KV. AUX. BUS 3 WIRE FUTURE 4 WIRE
23 KV. FUSED DISC. SW. 25-1 FUSE
S.P.S.T. 34.5 KV. 400 A. DISC. SW.
T.P.S.T. 34.5 KV. 400 A. AIR BREAK SW.
S.P.S.T. 34.5 KV. 400 A. DISC. SW.
To FUTURE 22/11 KV. TRANSR. BANK & FEEDERS.
G.E.Co. FKO 2.6-45 KV. O.C.B.s
G.E.Co. "P" POT. TRANSF. 22000/120 VOLT. TWO SHS.
23 KV. FUSED DISC. SW. 25-1 FUSE
STA. SERVICE TRANSFR. 1-25 KV.A. & 1-5 KV.A. 2300-1/1200-240 V. 230-115 V.
22 KV. FEEDER TO DARLINGTON
22 KV. FEEDER TO TIMMONSVILLE AND FLORENCE
22 KV. FEEDER TO FLORENCE
22 KV. FEEDER TO MARION
CAROLINA POWER & LIGHT CO.
ENGINEERING DEPARTMENT
RALEIGH, N. C.
FLORENCE - 110 KV - SUBSTATION
ONE LINE DIAGRAM
LOCATION Fflorence, S.C.
Scale N.T.S. Date JAN. 14, 1937
Drawn by W.K. W.R.H. Checked by R.E.H.
Approved by Dwg. No. RC-6521

Present and possible future one-line diagram of the Florence substation.

this old equipment as it later could be shifted to other parts of our system.

After a study of the estimated costs of various types of stations, we decided to use creosoted wood poles for the support of 110-kv bus and high-voltage air break switch and two-inch pipe for the 22-kv structure. As this station is on a stub 110-kv feeder from one of our main primary substations (Hartsville) with an oil circuit breaker on the feeder at the supply end, it was decided not to install a high-tension oil circuit breaker, but to use an automatic 115-kv air break switch.

Description of Florence Substation

This station is located on a 6.31-acre lot just outside and to the north of the city limits of Florence, S. C., a town of approximately 18,000 population.

Some of the reasons for selecting this site were: It is close to a railroad, permitting possible future railroad spur; outside city limits, thus avoiding city taxes, and well located with reference to the transmission lines leaving and entering the station. The lot is also fairly well drained, which is a decided advantage in this vicinity as the land in general is level. The lot is of sufficient size to provide for any possible future station additions.

This is a one-man station and a four-room frame cottage was built on the premises for his use. The cottage is equipped with an electric range and water heater and is heated with two 2000-watt electric heaters. Since the station is somewhat remote from city water supply, a deep well was dug and a pump house with automatic pumping equipment installed; also a septic tank and sewage system. A prefabricated sheet metal garage is provided for the operator's use. The premises have been beautified with flowers and shrubs and walkways and driveways made where needed. All shrubs and flowers were brought from pre-depression substations.

The main substation equipment, both electrical and mechanical for this station, is briefly as follows:

(a) Three 2000-kv-a, 110-22-kv outdoor, single phase, self-cooled transformers are installed on concrete foundations with foundation for a fourth transformer. No fire walls, barriers, water lines or other special fire fighting equipment is provided other than hand extinguishers for general use about the station. Approximately 4 in. of crushed stone was put in the switchyard and around the transformer foundations.

(b) A 50 ton capacity unenclosed structural steel hoist tower with 30 ton capacity lifting equipment, 50 ton capacity transformer transfer car and necessary track between the transformers and hoist tower is installed for handling the transformers and equipment.

(c) The transformers are connected to a 110-kv wire bus erected on pole structures. The bus connects to an automatic motor operated 110-kv air break switch. The switch in turn connects to the incoming 110-kv line from Hartsville. This switch, in general, takes the place of an oil circuit breaker. The switch is mounted on a four pole structure.

(d) The 2000-kv-a transformers on the 22-kv side connect to a 22-kv transformer bus and from this bus through outdoor metering type current and potential transformers to a 45-kv frame mounted automatic oil circuit breaker with necessary disconnecting switches and bypass group operated air break switch. These in turn connect to the 22-kv main feeder bus.

(e) To the main 22-kv feeder bus are connected:

(1) Three 275-kv-a, 22-2.3 kv transformers with necessary disconnecting switches. These transformers are used as a

source for ground current on the 22-kv system. A current transformer in the 2300-v delta operates an indicating ammeter, auxiliary ground, alarm relay, and polarizes directional ground relays on two of the four 22-kv feeders.

(2) One set of three phase thyrite lightning arresters.

(3) One 5-kv-a and One 25-kv-a, 22-kv-115/230 Volt transformers with fuses for station auxiliary service.

(4) Four 22-kv, 3-wire, 3-phase, feeders with a 45-kv outdoor frame mounted automatic oil circuit breaker with disconnecting switches and group operated bypass air break switches on each feeder. The bypass air break switches are used to connect the individual feeders to the auxiliary 22-kv bus in case of break—or failure or necessary maintenance. One of these feeders has a 22-kv potential transformer with suitable fuses for the purpose of synchronizing and voltage check.

(f) All the 22-kv buses, wiring and switches are mounted on a 15 bay pipe structure built of 2 in. structural pipe, 21 ft. high, 36 ft. wide and 60 ft. long. This structure is on concrete foundations. The buses and connections from bus to switches are copper tubing on 34.5-kv insulators, while the jumpers from the disconnecting switches to the breakers are cable. No soldered connections are used.

(g) The apparatus, both 110 and 22-kv is controlled from a switchboard connected through lead covered cable in underground conduit to the apparatus. The switchboard is a six panel board, each panel being 90 in. high by 24 in. wide and has mounted thereon all the necessary wiring, instruments, relays, meters, control switches, etc., necessary for the operation of a station of this kind from one central location.

(h) The switchboard is housed in a prefabricated insulated sheet metal building 14 ft. 8 in. x 26 ft. 8 in. x 8 ft. high. This building is provided with toilet, storage space and operating room with space allowed for additional panels when necessary. The building has concrete floor and is erected on concrete foundations. A man hole is provided as a part of, but outside the building for the convenient entrance of control cable and conduit.

(i) A 62-cell, 125-volt storage battery is installed in a separate wood frame house. Battery is provided with all necessary auxiliary equipment for its proper use in the control of the apparatus. The charging equipment is a One kw motor generating set of the diverter pole type. The motor generating set, battery panel, etc., is located in the switchboard house.

(j) A 5500 gallon oil tank, which was an old transformer case, is erected on concrete foundation with piping to the transformers and other equipment for the handling of oil.

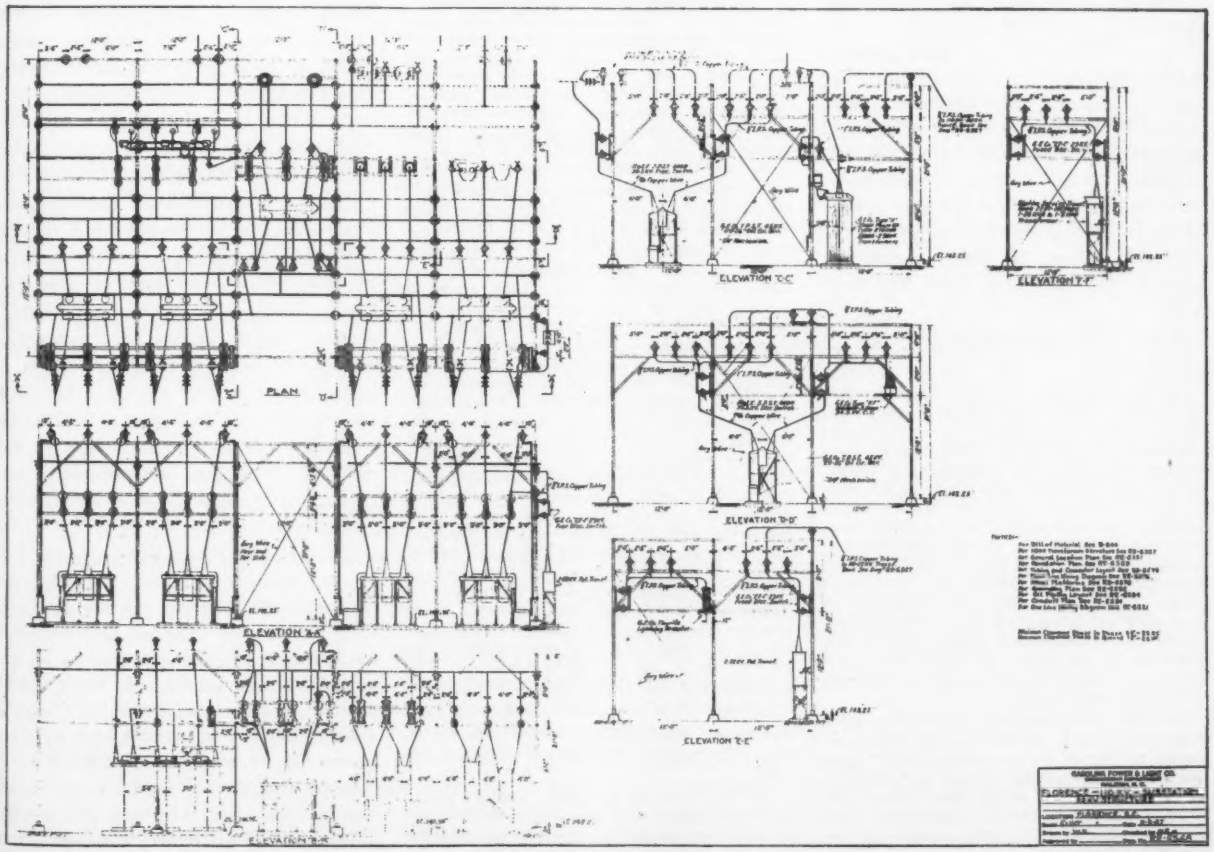
(k) All of this station except operator's cottage and garage is enclosed with 58 in.-2 in. mesh fence on metal posts set in concrete. Fence is topped with three strands of barbed wire the total height of the fence being approximately 7 ft.

In addition to the above it may be of general interest to make the following comments on the equipment and operation of this station:

Referring to the 22-kv switchyard structure and equipment, a third 22-kv bus was incorporated to facilitate the installation of totalizing metering and the connections to the low side of the main transformer bank. The metering was installed because of a state law in South Carolina which requires that all energy generated or sold shall be metered for tax purposes, and since this station is at terminus of 110-kv line feeding into distribution system, metering here was required. In the event new three-winding transformers are installed, this bus will be used for the tertiary winding.

It is also of interest to note that the 22-kv switchyard is built of standard 2-in. galvanized steel pipe. Some of the advantages we find, or claim, for pipe over other structural materials are:

It can be obtained quickly from any mill supply house, therefore a large warehouse stock is not necessary. Pipe can be cut and erected in field by an unskilled workman under proper supervision and from drawings showing only general assembly and not necessarily exact detail. There is not so much waste



22 kv switchyard structure and equipment.

to pipe as odd lengths left over can be used on other work. Structures built of pipe do not require shop drawings, nor erection drawings, as does structural steel with the attendant chance of mistakes, loss of time, larger drafting force and all other expensive details that go with structural steel work. Pipe structures can be erected from standard fittings. Bolt and clamp types are made by several different manufacturers. We use a floor flange of our own design for fastening structure to foundation. We find that galvanizing of standard pipe holds up satisfactorily over a long period of years and we have had no particular trouble with corrosion of pipe or footings. Some of the older types of fittings rust quite badly, but we have had no actual cause of failure from this. We have found that pipe is quite satisfactory for stations up to 66 kv and we have three 110-kv stations built of 3 in. and 2 in. pipe. Above 66 kv, due to increased electrical clearances necessary the matter of bracing and arranging the structure so that it is mechanically strong enough begins to get complicated and the cost begins to mount as compared to other structures. Our pipe structures are designed so as to be self-supporting in case of sudden failure of line wires attached thereto, and other stresses of like nature due to winds and other causes are taken care of by the proper use of braces and standard guy wire with turnbuckles for adjusting. Our system in general is located in the medium loading district which further favors the use of pipe.

Pipe structure, all things considered, compares very favorably with structural steel.

A few other points of possible general interest are:

(a) The use of a 110-kv motor operated air break switch. It provides a switch for clearing the high side of the transformer bank and opens by bank differential relays in case of transformer trouble. The operation of this switch or others of similar type on our system may cause the line to which this switch is connected to relay, but upon restoration of service the trouble causing the opening of the air break will be cleared from the line. The 110-kv line is a stub feeder from Hartsville, the operator at Hartsville energizing the line without voltage tests or intentional delay. There are seven 110-kv, six 66-kv, seventeen 22-kv and two 15-kv automatic air break switches in service on our system.

(b) The differential protection of the main transformer bank which is delta delta connected 110 kv/22 kv was obtained by using wye connected bushing current transformers installed in the delta of the high voltage side of the main transformer bank and delta connected bushing current transformer in the 22-kv bank oil circuit breaker. Stage tests were made to check the differential relay hookup and its operation was satisfactory. The actual relay tap settings as left were slightly different from the calculated settings because of the different characteristics of the two sets of bushing current transformers.

(c) The 22-kv transformer bus is protected with thyrite arresters located as near the transformers as was practicable to install them. Double spill gaps are mounted on the first pole beyond the dead-end pole of each feeder, ranging from 75 feet to 200 feet from the feeder oil circuit breakers. The grounded side of the gaps ties to the pole butt ground and also to the main station ground system. On two occasions the line spill gaps have flashed over. The gaps are set 3 in. on the line side and 1 in. on the grounded side.

(d) The three 275-kv-a, 22-kv transformers are for the purpose of securing a ground neutral. Normally the 22-kv system in this particular territory is grounded at four points approximately twenty-five miles apart. In case the 22-kv loop is open to Hartsville and Marion so as to isolate the Florence transformer bank and its two stub feeders, the grounding bank will be the only source for ground current. A current transformer in the 2300-volt delta of the grounding bank polarizes directional ground relays on the two tie-in feeders closing the 22-kv loop. If and when a new main bank is installed this grounding bank will be unnecessary as any new bank will be wye-wye-delta with 110-kv and 22-kv windings grounded.

(e) Each of the four feeders is equipped with three-shot, adjustable time, automatic reclosing relays. As the oil circuit breakers may have to interrupt currents near their capacity, the immediate reclosure is not used but is available for use in the future in case the breakers are replaced. Each feeder has induction overcurrent phase relays and instantaneous overcurrent relays. The two stub feeders have residual current relays while the other two which close the 22-kv loop have directional ground relays. Experience during the year and a half since the station was built has proven the value of the instantaneous and ground relays.

(f) In grounding the station, standard 5/8 in. x 8 ft. copperweld rods were used, one rod being driven near each structure footing and one near each piece of equipment. All were tied together with 2/0 stranded copper cable using solderless copper connectors. Every effort was made to see that all pieces of equipment were grounded, including the oil storage tank, 22-kv pole mounted gaps, 110-kv gaps on the station pole type structure, 110-kv gaps on the first line-structure away from the automatic air break switch, the station fence, the railroad track and the 22-kv overhead ground wire. Each gate in the fence was jumpered with 2/0 copper and the fence in turn tied to the station ground at several points. The measured ground resistance of the station ground sysem is 1.9 ohms. A lightning rod mounted on the hoist tower protects this station from direct strokes. The top of this rod is 65 feet above ground and 40 feet above the switching structure. The lightning rod is tied into the station ground.

(g) We have used a 62-cell battery here instead of the customary 60-cell battery so as to insure good voltage in all parts of the yard.

(h) To provide adequate lighting there are three 500-w and two 200-w flood lights normally connected to A-C station service but with automatic change-over scheme for emergency D-C service.

C. F. Hirshfeld

DR. C. F. HIRSHFELD, internationally known educator and engineer, Chief of Research of The Detroit Edison Company, died at Grace Hospital, Detroit, on April 19, 1939, after an illness of several months. Dr. Hirshfeld was distinguished in numerous fields, his work including consulting practice in several branches of engineering, many noted research activities, war service in 1918-19 with the rank of Lt. Colonel in the U. S. Ordnance Department, the writing of many books and papers on Engineering subjects (he was author of the chapter on Power in Dr. Charles A. Beard's composite work—"Toward Civilization" published in 1930), and in recent years the development of the P.C.C. street car, a revolutionary advance in the field of urban transportation.

In 1913 Dr. Hirshfeld became associated with The Detroit Edison Company as Chief of Research, a position held until his death. He organized the Research Department of this company, which is believed to have been the first such department established and maintained by an electricity supply company. Dr. Hirshfeld directed researches in a wide variety of fields including problems dealing with the design, construction, operation and maintenance of steam-electric power plants and the operation and interconnection of the electrical system; industrial electric heating and other load building efforts; disposal of industrial waste; problems in electric cable deterioration, electric welding, development of electric furnaces and new methods of generating electrical energy. He initiated many projects falling in highly specialized fields of physics, chemistry and electricity and was internationally recognized as an authority in many branches of engineering.

Dr. Hirshfeld's association with The Detroit Edison Company provided for the continuance of his practice as a private consultant. Under this arrangement, during the last seven years, he has served as Chief Engineer in the development of a modernized street car, designed more nearly to meet present-day requirements. Many of these so-called P.C.C. cars are now in use in the larger cities such as Brooklyn, Toronto, Pittsburgh, Washington, Baltimore, Chicago, San Diego and Los Angeles.

The Range Campaign of 1939

By J. R. Poteat

General Electric Company, Nela Park, Cleveland, Ohio

An address before the Sixth Annual Sales Conference, Edison Electric Institute, Chicago, March 21-24

GENERAL HUGH S. JOHNSON in a recent newspaper column made the interesting statement that every plan of action for the army is tested against a standard three-part formula as follows:

1. Why do it at all?
2. Why do it this way?
3. Why do it now?

As a matter of fact if any plan can satisfy these three tests with logical *"reasons why"* the chances for the success of such a plan are rather favorable.

Suppose we test our spring range plan against this formula:

1. Why have an activity?
2. Why have it in the form of a cooperative range campaign?
3. Is this the time to have it?

1. Why Have an Activity?

According to the dictionary, the opposite or antonym of "activity" is "passivity"—"inaction." Is "passivity" an attribute of the electrical business? Was there ever a more virile, a more progressive industry than the electrical industry? Progress is not the middle name of the electrical industry, it's the first name.

Not only is the electrical industry synonymous with progress and activity, but it has long since captured the imagination of the public. How exciting are its immense turbines, towering dams and high tension transmission lines—its X-ray tubes, radio, television, electric eyes, etc. No other industry is so intimately a part of every-day living or so completely occupies the horizon of future developments.

And one of the reasons why the electrical industry occupies so important a place is that it has become a vigorous selling industry—always selling itself, its accomplishments and its opportunities. To be sure its importance is also being sold by the emphasis of those in public life. If we were not important to the public, how could 1½ per cent of the family budget come in for so much discussion?

MR. POTEAT

No! Passivity is not for us. The electrical industry can only certify to its right to American business leadership by action, and commercial executives likewise gain their right to leadership by action. Activity is essential—and selling activity. A business that stands still—doesn't!

Selling is the real motive power behind our modern industrial machine. Money or materials may start a business, but only selling and salesmen can keep a business running. You have seen accountants audit a loss—but I ask you, did you ever see them audit a profit unless salesmen had made it possible? Contrast selling with your production of energy. This production is concentrated in a certain number of plants, located at strategic points with machinery and men ranked in their allotted places, all operating on a regulated schedule. Do you find it necessary to hold pep meetings, give prizes, and banquets to the power plant crew that turns out the greatest increase in kilowatt hours over the previous year? Of course not.

Selling on the other hand has no such routine, planned advantage as has production—selling is located everywhere—it must seek out its people. Production works with materials—selling works with the simplest and most complex, the hardest and the most sensitive, the most pleasing and most fickle of all materials—the human mind—and transforms prospects into customers. Plans and objectives for selling must be defined if selling is to be given direction and force.

Why have an activity, then?

1. We cannot subscribe to the principle of Passivity.

2. Selling is the motive power to assure continued growth and profits.

3. A plan for selling procedure is our only assurance that we can reach the objective we seek.

A plan of activity is essential!

The second test in our formula is—

2. Why Do It This Way?

Why a *cooperative* electric range activity?

In business parlance "cooperative" and "competitive" are opposites. But the reason why our plan must be cooperative is because we are in a competitive situation. The electrical industry against the field. The power of this industry is tremendous and when cooperatively applied it can be irresistible.

Money Power—The electrical utilities have over twelve billion dollars invested in the future of the industry. The manufacturers backing this plan with the utilities, have a net worth of one billion three hundred million dollars.

These same manufacturers are spending in consumer magazine and radio advertising to promote the electrical idea, from 2½ to 3 million dollars a year. And the utilities, in their local areas, are spending several times this amount.

Combine this money power in an organized cooperative program and the effect on our customers cannot but be tremendous and favorable. If we fail to use this force cooperatively we are prodigal to our responsibility toward our stockholders and customers.

If the electrical idea is to prevail, the electric range must prevail—for the electric range is the heart of the electric home. It has been my habit for some time to point out that the range is the heart of the kitchen by referring to the definition of a kitchen—the place where cooking is done. But the range has be-

come the heart of the electric home for these two simple, fundamental reasons:

(a) The service entrance required for the range is sufficient to provide for all the electrical services now available for the home—it thus changes a narrow street into a broad highway over which electrical service may be delivered to the home. Just as both metropolitan and rural areas are finding it necessary to widen the narrow streets and roads to accommodate greater traffic loads, so service entrances must be enlarged if electrical development in the homes is not to be seriously retarded. The range service entrance becomes an avenue of greater usefulness.

(b) When electricity is used for cooking, the direction of the development of that home becomes electrical. The electric range definitely stimulates other electrical uses in the home.

If this is true—and we all know it to be—then the electric range must be put over. If we believe in the electric home and the better standards of living that it brings to the family—and I know we do—the promotion of the electrical idea is essential. A complete electric service for the home is and will increasingly be our theme song.

Is the electric range profitable? Is the roaster profitable? Is the ironer profitable? Is lighting always profitable? These are all a part of the overall electrical service and are and should be vigorously promoted as such. Even if the electric range added no net to your balance sheet, it should be promoted because of its electrical influence in the home. Compare the addition of a range in an existing user home with a new lighting customer. This is not a place for a discussion of this subject. May I refer you to the March issue of *Electric Light and Power* to the article, "Ensemble Load Building Builds Profitable Diversity," for a useful contribution to this subject. But may I suggest that when a railroad undertakes to provide a transportation service, it does not eliminate one type of service, be it passenger or freight. No—it sells and provides a complete service—including excursions' branch line service, pick-up freight and all the rest. It frequently puts on truck and bus service to protect its business. The passenger service helps sell the freight service. The dining car service helps sell the passenger service, etc. And so in the electric home, lighting, refrigeration, cooking—all these services help sell still other electric services. But as long as cooking is non-electrical, progress toward our ideal—the electric home—will be retarded. If the electric range does nothing but give electrical direction to the home, it is highly profitable. And when the electric water heater is added, using the service originally supplied for the range, the profit attainable is large.

We have asked the question, why an activity?

We have asked the question, why a cooperative activity?

We have asked the question, why an electric range activity?

In our second test for the logic of this whole plan, let's ask, "Why the theme 'Electric Cooking Costs Less Than One-half What You Think'?"

It has been asserted by some in the industry that low cost has been definitely sold to the public—particularly in many territories where ranges have been promoted and sold for years. Two recent instances have come to my attention where this condition was claimed. The view was not supported by a house to house check in the field.

However, in order to double check what the campaign theme should be, a field test was conducted in which about 2300 women were asked a number of questions about electric cookery—1000 non-users of electric ranges were interviewed. Among other questions they were asked to guess what electric cooking would cost in the average family of four to five people. These estimates ranged from a low of $5 up to $35 as the high. 1284 other women, who own and use an electric range, were interviewed and their reply to the question on cost averaged $2.80 per month—and 80 per cent of these bills were under $3 per month. Over 54 per cent of this group were of the moderate income classification. Even you frequently have the experience of surprising your friends when you tell them how little your electric cooking costs are.

The overwhelming necessity of correctly informing your customers on electric cooking costs, if you are to gain the opportunity of presenting its further advantages, has dictated the theme of the April-May Campaign. The backbone of the plan which is designed to tell the story that "Electric Cookery Costs One-half of What You Think" is a series of

The Modern Kitchen Bureau's comprehensive and interesting exhibit at the Sixth Annual Sales Conference at Chicago attracted much attention from commercial managers from all sections of the country. The five panels show the variety of materials produced by the Bureau for each of its five programs. The arrows and circles which appear on the panels are illuminated with flashers, arranged so as to carry the eye progressively from one panel to another. Below the panels appear the posters of the Bureau's four appliance campaigns, with a central display tying in the activity with the World's Fairs at San Francisco and New York.

five full-page, two-color advertisements in the *Saturday Evening Post*. These ads are on display with the other Modern Kitchen Bureau material. They have been pretested for "attention value," "read through" and "retention of the message." They rank very high on these tests.

Just what do these five ads mean in terms of exposure of this idea to the public? Let me illustrate. If, in the year 1815—just 124 years ago—a reader had been exposed to the first of these ads one minute, then a second person for a minute, and a third-minute exposure, etc., one exposure per minute from 1815 on, it would take until 1939 for all the exposures represented by this advertising to be concluded. At one exposure per minute it would take 124 years to create these 65,000,000 exposures to the reading public.

The field tie-in, with window streamers, counter cards, letter stickers, envelope stuffers, selling manuals, etc., constitutes a barrage of advertising and selling activity which should make the quota of 80,000 ranges for April and May easy to attain.

The reason for an activity has been established.

The reasons why we should make it a cooperative electric range campaign with the chosen theme are clear—and now for

The third of the three tests in the formula of the army—

Why Do It Now?

Dr. Bennion, in an address to this group last year, said that in our industry there are three M's—Men, Money, and Materials, but the greatest of these is Men. Like the three legs on a stool, we can't get along without one of these three. But as an addition to this important triumvirate, I want to add a fourth—Momentum. To illustrate this, I'll read from a prominent woman editor:

"The electric range of today has definite assets in ease, cleanliness, less heating up of the user and place used, better and more definite control of cooking heat—but the greatest asset of all is perhaps the opportunity to take advantage of a turning tide, the crest of a wave. During the last year I should say this has taken place and for the first time I feel that I can say definitely, the trend is toward electricity. . . . Today is a day when majorities sweep the country rapidly and minorities are downed. The pro-electrics are coming into the majority. The new homes field, whether new homes for old families or new homes for new families, will go electric where electricity rates make its use possible. That, of course, is like all pre-election forecasts but puts emphasis on the point that the present marks the turn toward electricity."

Rate reductions, which have wiped out large sections of gross revenue, make other added revenue imperative. This revenue can only be regained by selling —and delays are out of the question.

The timing of this activity requires little further elaboration. The old adage, "There is no time like the present," aptly applies to this activity.

Now—We have tested our plan and
We know of the necessity of this activity—
We know that its character is desirable—
We know that now is the time for it.

What can you do in your own local companies to help assure the success of this Spring Electric Range Campaign?

(1) Appoint a staff man in your organization whose sole duty shall be to handle every detail of the campaign.

(2) Call each range distributor in your territory into consultation to encourage him to tie his retailers into the plan.

(3) Arrange a package deal of Bureau material in which you make available cards, banners, stickers and other promotion to identify retailers with the plan.

(4) Give local window display prizes and stimulate retailers and salesmen in all the ways you know so well how to use.

But further specifications beyond those written in the plan of the bureau are unnecessary. They are complete in the plan book.

The Plan Book is like your transmission lines—loaded with energy but absolutely no good unless someone, somewhere makes a connection with it and uses that energy. It's like a violin which with its four strings in tune is capable of great music only when a bow and a man make use of it. With the four strings of this activity in tune—the utility, manufacturer, distributor and independent retailer working together—your individual company can make contact with the energy and potentiality of the plan to put it to work for you—and the objective of 80,000 ranges during the months of April and May will be easily exceeded. So, on your mark, get set—go.

John R. Fenniman

JOHN R. FENNIMAN, treasurer of the Consolidated Edison Company of New York, Inc., died of a heart attack at his home, 484 East 17th Street, Brooklyn, April 21.

Mr. Fenniman was born in Brooklyn on July 21, 1879, and attended public school and high school there. He began his business career with the Brooklyn Union Gas Company as a collector, later becoming bookkeeper, cashier and assistant to the manager of the district office.

Mr. Fenniman went to Consolidated Gas Company (predecessor of Consolidated Edison Company) as a clerk in 1904. He later established the first information bureau for the company in its Third Avenue District Office. In 1905 he was made assistant superintendent at Third Avenue and a year later superintendent of the new district office at 1911 Amsterdam Avenue.

In 1919, Mr. Fenniman became assistant general superintendent of the Commercial Department of the Consolidated Gas Company. Three years later he was put in charge of placing a new stock issue among customers and employees of the Gas Company. In 1923 he was appointed assistant treasurer, and in 1929 became treasurer. He continued as treasurer when mergers of various companies in the group formed the present Consolidated Edison Company.

Bibliography

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ing Effect of Paralleling Through Transmission Lines.

Solution of Networks and Calculating Boards

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Board Pays Its Cost Eight Times—LeClair—*Elec World*, Nov. 23, 1935; *West.* 548.

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Relay Handbook & Supplement—*N.E.L.A.* Solution of Networks, 891; General Part of Oil Circuit; Breaker Sections of Westinghouse Electric & General Electric Company Catalogues.

General

Some Phases of the Operation of an Interconnected System—Fitch—*N.E.L.A.*, Overhead Sys. Com., Feb. 1932.

Phase Shifting to Control Power Flow

Application of Large Phase-Shifting Transformer on an Interconnected System Loop—Lyman & North—*A.I.E.E.* Trans. Vol. 57, 1938, Page 579.

Controlling Power Flow With Phase Shifting Equipment — Lyman — *A.I.E.E.* Trans. Vol. 49, 1930, Page 825.

Combined Overhead and Underground Network

(*Continued from page 252*)

other advantage is the short time required to make extensions of the system using the overhead transformer installations. The changeover of an old building to alternating current can be made in a short time, and it is at least a convenience to be able to have service available when wanted.

Operation

The operation of the network has been entirely satisfactory to date. Two cases of primary cable faults have occurred which were cleared by correct operation of the network protectors without service interruption. No known failures of the secondary cables have occurred.

Safeguarding Electric Utility Earnings

(*Continued from page 227*)

time, we are keenly conscious of our increasing responsibilities to the public we serve. For the future all that we ask is reasonable freedom of action and a fair consideration of our problems by the public, by our investors and by regulatory authorities. There is assurance of a broadening understanding by the public of our policies and our objectives. This is probably the most encouraging note of all, for in the final analysis the public will have the deciding word—and that, I am confident, will be to give this business along with all business the chance it needs to do a job.

Design of Substations

(*Continued from page 262*)

designation engraved directly on them. To make even more definite distinction in certain cases a few switches are made "pull-turn."

Portable shields are used to cover, or block, control switches and synchronizing plugs where unusual hazard to operation or personnel exists.

Adequate lighting is an important feature in providing for safe operation and maintenance. Fig. 7 shows a large railroad supply substation illuminated at night. It will be noted that the air break switches on the upper structure 90 feet above the ground level can be clearly seen.

For the basic protection of the workmen we employ:

1. Carefully prepared Permanent Instructions for conducting work (inaugurated in 1913).

2. A complete system of tagging and blocking supervised by the operator and checked jointly with the workman to whom the hold off card is issued.

3. Portable barriers of various designs (depending upon the situation involved).

4. Careful personnel training.

Our records indicate that even with all of these opportunities for protective "size up" the protection is not complete. The uncertainty of the human element must be recognized and we endeavor to do this by the employment of safety watchmen on every job where there is any question of hazard to the workmen or to service. It is the sole duty of these watchmen to "size up" and supervise personal safety at the location of their assignment; safety watchmen are not permitted to engage in work, or to leave while it is in progress. We believe that worth while results are obtained from this procedure.

CONVENTIONS AND MEETINGS

MAY

1-4	Engineering Committees, Edison Electric Institute, Edgewater Beach Hotel, Chicago, Ill.
1-5	Annual short course and conference, Electric Meters and Relays, University of Florida, Gainesville, Fla.
2-4	Chamber of Commerce of the USA, Washington, D. C.
8-12	National Fire Protection Association, Chicago, Ill.
14-18	National Electrical Manufacturers Association, The Homestead, Hot Springs, Va.
24-26	Pacific Coast Electrical Association, Huntington Hotel, Pasadena, Calif.
21-25	National Electrical Wholesalers Association, The Homestead, Hot Springs, Va.
22-25	National Association of Purchasing Agents, San Francisco, Calif.
26-27	Northwest Electric Light and Power Association, Accounting and Business Practice Section, Hotel Vancouver, Vancouver, B. C.
26-30	Westinghouse Agent-Jobbers Association, The Homestead, Hot Springs, Va.

JUNE

6-8	EDISON ELECTRIC INSTITUTE, Waldorf-Astoria Hotel, New York, N. Y.
18-21	Public Utilities Advertising Association, New York, N. Y.
21-24	Canadian Electrical Association, Digby, N. S.
26-29	National Association of Cost Accountants, Atlantic City, N. J.
26-30	American Institute of Electrical Engineers, San Francisco, Calif.
27-30	National District Heating Association, Pennsylvania Hotel, New York, N. Y.

JULY

26-29	American Society of Civil Engineers, St. Francis Hotel, San Francisco, Cal.

AUGUST

21-25	Illuminating Engineering Society, Hotel Fairmont, San Francisco, Cal.

OCTOBER

2-6	National Restaurant Association, Chicago, Ill.
5	Third Annual Conference, Commercial Electric Cooking Council, Chicago, Ill.
9-12	American Gas Association, New York City, N. Y.
9-12	National Electrical Contractors Association, Bellevue-Stratford Hotel, Philadelphia, Pa.
16-20	National Safety Council, Atlantic City, N. J.
23-27	National Electrical Manufacturers Association, Palmer House, Chicago, Ill.